

# IMAGE FORMING PROCESS AND IMAGE FORMING APPARATUS

## BACKGROUND OF THE INVENTION

### Field of the Invention

The present invention relates to an electrophotographic image forming process, an image forming apparatus which are capable of producing images at high speed and conserving energy and is highly suitable for operation over the long run.

### Description of the Related Art

In a cooling and releasing process in an image-fixing process using a belt, if an electrophotographic image-receiving sheet is released from an image-fixing belt at a high temperature, offset occurs in which a toner-image-receiving layer and a toner layer remain on the surface of the belt. The resulting electrophotographic image-receiving sheet may often have decreased glossiness. In addition, the belt is stained and often invites decreased image quality in operation over the long run.

To solve these problems, Japanese Patent Application Laid-Open (JP-A) No. 05-2349 and JP-A No. 05-107960 propose a process for cooling a belt in a cooling and releasing process and the improvement on efficiency in such a process.

Specifically, JP-A No. 05-2349 discloses an image fixing apparatus having forced draft cooling means in a cooling section

between a heating section and a releasing section so as to efficiently cool a film and a recording material concurrently.

JP-A No. 05-107960 discloses an endless belt image-fixing apparatus which has a cooling stabilizer and temperature control means and is capable of controlling the temperature.

JP-A No. 09-179421 proposes an image-fixing belt for an electrophotographic image forming apparatus, which image fixing belt comprises a belt substrate, an intermediate elastic layer having a specific thermal conductivity and being arranged on the substrate, and a surface elastic layer of a curable silicone rubber arranged on the intermediate elastic layer. This technique specifies the thermal conductivity of the belt member but does not take into consideration the heat capacities of the belt member, electrophotographic image-receiving sheet and toner which are actually to be cooled.

As thus described, conventional technologies do not sufficiently investigate the heat capacities of the belt member, electrophotographic image-receiving sheet, and toner to be cooled actually, and demands have been made on further improvements and development in this point.

## SUMMARY OF THE INVENTION

Accordingly, an object of the present invention is to provide an electrophotographic image forming process, an image forming apparatus which are capable of producing images at high speed and conserving energy, can prevent offset and can avoid stain of a belt in

operation over the long run, by specifying the heat capacity of a belt member itself and the total heat capacity of the belt member, an electrophotographic image-receiving sheet, and a toner to be cooled.

After intensive investigations to achieve the above object, the present inventors have found the following findings.

Namely, the image forming process can have an increased cooling efficiency, can produce images at high speed and can conserve energy due to reduced energy consumption of a cooling fan by specifying the upper limits of the heat capacity of the belt member, and the total heat capacity of the belt member, the electrophotographic image-receiving sheet, and the toner, more specifically, by specifying the upper limits of the heat capacity per unit time and the heat capacity per unit area in a cooling process.

The offset and stain of the belt in operation over the long run (about 100000-sheets output) can be inhibited by using a highly releasing material as a surface layer of the belt member in addition to employing the above specified heat capacities. This advantage can be obtained more effectively by using a fluorocarbonsiloxane rubber having at least one of a perfluoroalkyl ether group and a perfluoroalkyl group in its principal chain as the highly releasing material.

In addition, curling and cracking with varying environment can be inhibited, and thereby images with glossy photographic image quality can be produced by using an electrophotographic image-receiving sheet including a double-sided laminated paper as

a support, and a toner-image-receiving layer arranged on at least one side of the support, which toner-image-receiving layer includes a thermoplastic resin and has a thickness of 3  $\mu\text{m}$  or more. The present invention has been accomplished based on these findings.

Specifically, the present invention provides an image forming process including the step of fixing a toner onto an electrophotographic image-receiving sheet with the use of a belt fixing and smoothing apparatus to thereby form an electrophotographic image, the belt fixing and smoothing apparatus including a hot-pressing member, a belt member, a cooling device, and a cooling-releasing section, in which a total heat capacity per unit area in portions where the belt member, the toner, and the electrophotographic image-receiving sheet are in contact with one another is 840 J/K/m<sup>2</sup> or less. This process is capable of producing images at high speed and conserving energy, can prevent offset and can avoid stain of the belt in operation over the long run, by specifying the heat capacities of the belt member, the electrophotographic image-receiving sheet, and the toner.

The present invention provides an image forming apparatus including the means of fixing a toner onto an electrophotographic image-receiving sheet with the use of a belt fixing and smoothing apparatus to thereby form an electrophotographic image, the belt fixing and smoothing apparatus including a hot-pressing member, a belt member, a cooling device, and a cooling-releasing section, in which a total heat capacity per unit area in portions where the belt

member, the toner, and the electrophotographic image-receiving sheet are in contact with one another is  $840 \text{ J/K/m}^2$  or less. This apparatus is capable of producing images at high speed and conserving energy, can prevent offset and can avoid stain of the belt in operation over the long run, by specifying the heat capacities of the belt member, the electrophotographic image-receiving sheet, and the toner.

Further objects, features and advantages of the present invention will become apparent from the following description of the preferred embodiments with reference to the attached drawing.

#### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic diagram showing an example of a belt fixing and smoothing apparatus of cooling and releasing system for use in the present invention.

FIG. 2 is a schematic diagram showing an example of an electrophotographic apparatus for use in the present invention.

FIG. 3 is a schematic diagram showing another example of the belt fixing and smoothing apparatus of cooling and releasing system for use in the present invention.

FIG. 4 is a schematic view of an example of an electrophotographic apparatus for use in the present invention.

#### DESCRIPTION OF THE PREFERRED EMBODIMENTS

<Image forming process and Image forming apparatus>

The image forming process of the present invention produces an electrophotographic image by fixing a toner to an electrophotographic image-receiving sheet using a belt fixing and smoothing apparatus of cooling and releasing system.

The image forming apparatus of the present invention produces an electrophotographic image by fixing a toner to an electrophotographic image-receiving sheet using a belt fixing and smoothing apparatus of cooling and releasing system.

According to the present invention, the total heat capacity per unit area of the belt member, the toner, and the electrophotographic image-receiving sheet in portions where these components are in contact with one another is  $840 \text{ J/K/m}^2$  or less and is preferably  $800 \text{ J/K/m}^2$  or less, and more preferably  $600 \text{ J/K/m}^2$  or less.

If the total heat capacity per unit area exceeds  $840 \text{ J/K/m}^2$ , loaded energy for cooling in a cooling process increases, the cooling process thereby becomes longer, and energy consumption increases. Thus, energy consumption and size of an electrophotographic apparatus increase, inviting problems in practical use. If the total heat capacity per unit area exceeds  $840 \text{ J/K/m}^2$  in a belt image-fixing device having a specific practical size and cooling and heating heat capacity, its image-fixing speed must be reduced to thereby decrease efficiency in process.

The belt member in the belt fixing and smoothing apparatus preferably has a heat capacity per unit time of  $8 \text{ J/K/sec}$  or less and

a thickness of 200  $\mu\text{m}$  or less and more preferably has a heat capacity per unit time of 6.5 J/K/sec or less and a thickness of 150  $\mu\text{m}$  or less.

To reduce the releasing temperature to thereby prevent offset and improve glossiness, the total heat capacity of the belt member and the electrophotographic image-receiving sheet must be reduced. If the belt member has a heat capacity per unit time exceeding 8 J/K/sec and a thickness exceeding 200  $\mu\text{m}$ , the thickness of the support and toner-image-receiving layer in the electrophotographic image-receiving sheet must be reduced. The resulting electrophotographic image-receiving sheet has decreased rigidity, has decreased handleability, does not receive the toner satisfactorily and bears images with decreased quality. In addition, heat load on the belt member in a return process, in which the belt member after releasing the electrophotographic image-receiving sheet returns to an image-fixing section, increases and heat energy necessary for the image fixing process becomes excessively large.

The total heat capacity per unit time of the belt member, the toner, and the electrophotographic image-receiving sheet is preferably 20 J/K/sec or less, and more preferably 14 J/K/sec or less.

If the total heat capacity per unit time exceeds 20 J/K/sec, loaded energy for cooling in a cooling process may increase, the cooling process may become longer, and energy consumption may increase. Thus, energy consumption and size of the

electrophotographic apparatus may increase, inviting problems in practical use.

The heat capacity per unit area of the belt member in a portion where the belt member is in contact with the electrophotographic image-receiving sheet is preferably  $500 \text{ J/K/m}^2$  or less, and more preferably  $300 \text{ J/K/m}^2$  or less.

If the heat capacity per unit area of the belt member exceeds  $500 \text{ J/K/m}^2$ , the thickness of the substrate and toner-image-receiving layer in the electrophotographic image-receiving sheet may be reduced. The resulting electrophotographic image-receiving sheet may have decreased rigidity, have decreased handleability, may not receive the toner satisfactorily and may bear images with decreased quality. Heat load on the belt member in a return process, in which the belt member after releasing the electrophotographic image-receiving sheet returns to an image-fixing section, may increase and heat energy necessary for the image fixing may become excessively large. In addition, if the heat capacity per unit area of the belt member exceeds  $500 \text{ J/K/m}^2$  in a belt image-fixing device having a specific practical size and cooling and heating heat capacity, its image-fixing speed must be reduced to thereby decrease efficiency in a process.

The heat capacities can be determined by calculation from the measured density, thickness, and specific heat of each layer of the belt member, each layer of the electrophotographic image-receiving sheet, and the toner.



In addition to the requirements in heat capacity, it is preferred that the temperature at the interface between a surface of the belt member and a surface of the electrophotographic image-receiving sheet in the cooling-releasing section is at highest 20°C higher than the higher glass transition point  $T_g$  between a resin constituting a toner-image-receiving layer of the electrophotographic image-receiving sheet and a binder resin of the toner. This temperature is more preferably equal to or lower than the higher glass transition point  $T_g$ .

If the temperature is more than 20°C higher than the higher glass transition point  $T_g$ , at least one of the toner and the toner-image-receiving layer may become susceptible to offset, and the belt member may be stained in operation over the long run to thereby deteriorate the resulting images.

As is described above, the image forming process of the present invention fixes the toner using the belt fixing and smoothing apparatus of cooling and releasing system and the electrophotographic image-receiving sheet satisfying the specific requirements in heat capacity. The electrophotographic image-receiving sheet, the toner, and the belt fixing and smoothing apparatus for use in the present invention will be illustrated in further detail below.

#### <Image-receiving Sheets for Electrophotography>

The image-receiving sheet for electrophotography (hereinafter may be simply referred to as "image-receiving sheet") of

the present invention comprises a support, and at least one toner-image-receiving layer arranged on the support. The support comprises a base, and a thermoplastic resin layer arranged on at least one side of the base. It may further comprise at least one of additional layers appropriately selected according to necessity. Such additional layers include, for example, surface protective layers, interlayers, undercoat layers, cushioning layers, charge-control or antistatic layers, reflective layers, color-control layers, storage-stability improving layers, adhesion inhibiting layers, anticurling layers, and smoothing layers. Each of these layers can have a single layer structure or a multilayer structure.

- Base -

The base for use in the present invention is not specifically limited and can be appropriately selected according to an intended purpose, as long as it can endure at an image-fixing temperature and can satisfy requirements in smoothness, whiteness, slidability, frictionality, antistatic properties, and depressions after image-fixing. Such bases generally include, for example, photographic supports such as paper and synthetic polymers (films) as described in "Basis of Photographic Technology -silver halide photography-" edited by The Society of Photographic Science and Technology of Japan, Corona Publishing Co., Ltd., pp. 223-240 (1979).

Examples of the base include synthetic paper (synthetic paper made from, for example, polyolefins or polystyrenes), woodfree paper, art paper, (double-sided) coated paper,

(double-sided) cast coat paper, mixed paper made from polyethylene or another synthetic resin pulp and natural pulp; Yankee paper, baryta paper, wallpaper, backing paper, synthetic resin- or emulsion-impregnated paper, synthetic rubber latex-impregnated paper, paper comprising a synthetic resin as an internal additive, paperboard, cellulosic fiber paper, and other paper supports; films and sheets of plastics or polymers such as polyolefins, poly(vinyl chloride), poly(ethylene terephthalate), poly(styrene methacrylate), poly(ethylene naphthalate), polycarbonate-poly(vinyl chloride), polystyrenes, polypropylenes, polyimides, celuloses such as triacetylcellulose; films and sheets obtained by subjecting these plastic films and sheets to a treatment, such as addition of a pigment such as titanium oxide for imparting white-reflecting properties; fabrics; metals, and glass.

Each of these bases can be used alone or in combination as a multilayer assemblage.

Examples of the base can also be found in JP-A No. 62-253159 (pp. 29-31 in Japanese), JP-A No. 01-61236 (pp. 14-17 in Japanese), JP-A No. 63-316848, JP-A No. 02-22651, JP-A No. 03-56955, and U.S. Pat. No. 5,001,033.

The base preferably has a high surface smoothness. More specifically, its surface roughness in terms of Oken type smoothness is preferably 210 seconds or more, and more preferably 250 seconds or more. The Oken type smoothness is preferably around 600 seconds or less. If the surface roughness in terms of Oken type

smoothness is less than 210 seconds, the resulting images may have insufficient quality.

The Oken type smoothness as used herein is the smoothness specified in the method B, No. 5 of Japan Technical Association of the Pulp and Paper Industry (JAPAN TAPPI) .

The thickness of the base is generally from 25 $\mu$ m to 300 $\mu$ m, preferably from 50 to 260  $\mu$ m, and more preferably from 75 $\mu$ m to 220 $\mu$ m.

The stiffness (rigidity) of the base is not specifically limited, can be appropriately selected depending on an intended purpose and are preferably near to those in bases for use in color silver halide photography when the sheet is used as an image-receiving sheet of photographic quality.

The density of the base is preferably 0.7 g/cm<sup>3</sup> or more for better image-fixing properties.

The thermal conductivity of the base is not specifically limited, can be appropriately set depending on an intended purpose and is preferably 0.50 kcal/m·h·°C or more as determined at a temperature of 20°C and a relative humidity of 65% for better image-fixing properties.

The thermal conductivity can be determined, for example, by conditioning a transfer paper according to JIS P 8111 and determining the thermal conductivity of the conditioned transfer paper according to a procedure described in JP-A No. 53-66279.

The base may further comprise various additives

appropriately selected according to the purpose within ranges not adversely affecting the advantages of the present invention.

Such additives include, but are not limited to, brightening agents (whitening agents), conductant agents, fillers, and pigments and dyes such as titanium dioxide, ultramarine blue, and carbon black.

The base may be subjected to any of surface treatments and/or primary coatings at one or both sides thereof to thereby improve adhesion with another layer such as a thermoplastic resin layer arranged thereon.

Such surface treatments include, for example, embossing or printing to form a glossy surface, a fine surface described in JP-A No. 55-26507, a matte surface or a tweed surface, corona discharge treatment, flame treatment, plasma treatment, and other activation treatments.

Each of these treatments can be employed alone or in any combination. For example, the base is subjected to the embossing and then to the activation treatment. It may be further subjected to the undercoating treatment after a surface treatment such as the activation treatment.

The base may be coated with a hydrophilic binder, a semiconductive metal oxide such as alumina sol or tin oxide, and an antistatic agent such as carbon black on its front side and/or back side. Typical disclosure of these coated bases can be found in, for example, supports in JP-A No. 63-220246.

- Thermoplastic resin layer -

Each at least one thermoplastic resin layer is arranged on both sides of the base. The total thickness of the thermoplastic resin layers is preparedly 3  $\mu\text{m}$  or more, and more preferably 5  $\mu\text{m}$  or more.

When raw paper is used as the base, the thermoplastic resin is not specifically limited, may be selected according to the purpose and includes, for example, polyolefins, poly(vinyl chloride)s, poly(ethylene terephthalate)s, polystyrenes, polymethacrylates, polycarbonates, polyimides, and triacetylcellulose, of which polyolefins are preferred. Each of these resins can be used alone or in combination.

Generally, a low-density polyethylene is used as the polyolefin. However, for improving the thermal resistance of the support, it is preferred to use a polypropylene, a blend of a polypropylene and a polyethylene, a high-density polyethylene, or a blend of the high-density polyethylene and a low-density polyethylene. From the viewpoint of cost and its suitability for the lamination, it is preferred to use the blend of the high-density polyethylene and the low-density polyethylene.

The blend of the high-density polyethylene and the low-density polyethylene is used in a blend ratio (a mass ratio) of, for example, from 1:9 to 9:1, preferably from 2:8 to 8:2, and more preferably from 3:7 to 7:3. When the polyethylene is applied to both sides of the support, the polyolefin to be applied to the back

side of the support is, for example, preferably the high-density polyethylene or a blend of the high-density polyethylene and the low-density polyethylene. The molecular weight of the polyethylenes is not particularly limited. Desirably, both of the high-density polyethylene and the low-density polyethylene have a melt index of 1.0 g/10min to 40 g/10min. and a high extrudability.

The sheet or film to be laminated may be subjected to a treatment to impart white reflection thereto. For example, a pigment such as titanium dioxide is incorporated into the sheet or film.

The thickness of the support is preferably from 25  $\mu\text{m}$  to 300  $\mu\text{m}$ , more preferably from 50  $\mu\text{m}$  to 260  $\mu\text{m}$ , and further preferably from 75  $\mu\text{m}$  to 220  $\mu\text{m}$ . The support can have any rigidity according to the purpose. When it is used as a support for electrophotographic image-receiving sheet with photographic image quality, the rigidity thereof is preferably near to that in a support for use in color silver halide photography.

#### <Toner-image-receiving Layer>

The toner-image-receiving layer is an image-receiving layer for receiving a color or black toner to form an image. The toner-image-receiving layer receives a toner for image formation from a development drum or an intermediate transfer member by action of (static) electricity or pressure in a transfer process and fixes the toner as an image by action of, for example, heat and/or pressure in an image-fixing process.

The toner-image-receiving layer mainly comprises a thermoplastic resin and may further comprise a releasing agent and other components.

The electrophotographic image-receiving sheet preferably has the toner-image-receiving layer comprising the thermoplastic resin at least on one side of the support. The thickness of the toner-image-receiving layer is preferably 3  $\mu\text{m}$  or more, and more preferably 4  $\mu\text{m}$  or more. Thus, curling and cracking with varying environment can be inhibited, and glossy images with photographic image quality can be produced. The support is preferably a double-sided laminated paper.

#### - Thermoplastic Resins -

Thermoplastic resins for use in the present invention are not specifically limited as long as they can deform at temperatures during, for example, image-fixing and can receive the toner. They can be appropriately selected depending on an intended purpose and are preferably similar or the same resin as the binder resin of the toner. Polyester resins, styrene resins, styrene-butyl acrylate, and other copolymer resins are often used in most of such toners, and the image-receiving sheet preferably comprise any of these polyester resins, styrene resins, styrene-butyl acrylate, and other copolymer resins more preferably in an amount of 20% by mass or more. As the thermoplastic resins, styrene-acrylic ester copolymers and styrene-methacrylic ester copolymers are also preferred.

Examples of the thermoplastic resins are (i) resins each



having an ester bond, (ii) polyurethane resins and similar resins, (iii) polyamide resins and similar resins, (iv) polysulfone resins and similar resins, (v) poly(vinyl chloride) resins and similar resins, (vi) poly(vinyl butyral) and similar resins, (vii) polycaprolactone resins and similar resins, and (viii) polyolefin resins and similar resins.

The resins (i) having an ester bond include, for example, polyester resins obtained by condensation of a dicarboxylic acid component with an alcohol component. Such dicarboxylic acid components include, but are not limited to, terephthalic acid, isophthalic acid, maleic acid, fumaric acid, phthalic acid, adipic acid, sebacic acid, azelaic acid, abietic acid, succinic acid, trimellitic acid, pyromellitic acid, and other dicarboxylic acids. Each of these dicarboxylic acid components may have a sulfonic acid group, a carboxyl group, or another group substituted thereon. The alcohol components include, but are not limited to, ethylene glycol, diethylene glycol, propylene glycol, bisphenol A, diether derivatives of bisphenol A (e.g., an ethylene oxide diadduct of bisphenol A, and a propylene oxide diadduct of bisphenol A), bisphenol S, 2-ethylcyclohexyldimethanol, neopentyl glycol, cyclohexyldimethanol, glycerol, and other alcohols. Each of these alcohol components may have a hydroxyl group or another group substituted thereon. The resins (i) also include poly(methyl methacrylate), poly(butyl methacrylate), poly(methyl acrylate), poly(butyl acrylate), and other polyacrylic ester resins and polymethacrylic ester resins, polycarbonate resins, poly(vinyl

acetate) resins, styrene-acrylate resins, styrene-methacrylate copolymer resins, and vinyltoluene-acrylate resins.

Typical disclosure of the resins (i) can be found in, for example, JP-A No. 59-101395, JP-A No. 63-7971, JP-A No. 63-7972, JP-A No. 63-7973, and JP-A No. 60-294862.

Such polyester resins are commercially available under the trade names of, for example, Vylon 290, Vylon 200, Vylon 280, Vylon 300, Vylon 103, Vylon GK-140, and Vylon GK-130 from Toyobo Co., Ltd.; Tuftone NE-382, Tuftone U-5, ATR-2009, and ATR-2010 from Kao Corporation; Elitel UE 3500, UE 3210, and XA-8153 from Unitika Ltd.; and Polyestar TP-220, and R-188 from Nippon Synthetic Chemical Industry Co., Ltd.

The acrylic resins are commercially available under the trade names of, for example, Dianal SE-5437, SE-5102, SE-5377, SE-5649, SE-5466, SE-5482, HR-169, HR-124, HR-1127, HR-116, HR-113, HR-148, HR-131, HR-470, HR-634, HR-606, HR-607, LR-1065, LR-574, LR-143, LR-396, LR-637, LR-162, LR-469, LR-216, BR-50, BR-52, BR-60, BR-64, BR-73, BR-75, BR-77, BR-79, BR-80, BR-83, BR-85, BR-87, BR-88, BR-90, BR-93, BR-95, BR-100, BR-101, BR-102, BR-105, BR-106, BR-107, BR-108, BR-112, BR-113, BR-115, BR-116, and BR-117 from Mitsubishi Rayon Co., Ltd.; Eslec P SE-0020, SE-0040, SE-0070, SE-0100, SE-1010, and SE-1035 from Sekisui Chemical Co., Ltd.; Himer ST 95, and ST 120 from Sanyo Chemical Industries, Ltd.; and FM 601 from Mitsui Chemicals, Inc.

The poly(vinyl chloride) resins and similar resins (v) include,

for example, poly(vinyl chloride) resins, poly(vinylidene chloride) resins, vinyl chloride-vinyl acetate copolymer resins, and vinyl chloride-vinyl propionate copolymer resins.

The poly(vinyl butyral) and similar resins (vi) include, for example, poly(vinyl butyral), polyol resins, as well as ethylcellulose resins, cellulose acetate resins, and other cellulosic resins. These resins are also commercially available from, for example, Denki Kagaku Kogyo Kabushiki Kaisha and Sekisui Chemical Co., Ltd. The poly(vinyl butyral) for use herein preferably comprises vinyl butyral in a content of 70% by mass or more and has an average polymerization degree of preferably 500 or more and more preferably 1000 or more. Such poly(vinyl butyral) is commercially available under the trade names of, for example, Denka Butyral 3000-1, 4000-2, 5000A, and 6000C from Denki Kagaku Kogyo Kabushiki Kaisha; and Eslec BL-1, BL-2, BL-3, BL-S, BX-L, BM-1, BM-2, BM-5, BM-S, BH-3, BX-1, and BX-7 from Sekisui Chemical Co., Ltd.

The polycaprolactone resins and similar resins (vii) further include, for example, styrene-maleic anhydride resins, polyacrylonitrile resins, polyether resins, epoxy resins, and phenol resins.

The polyolefin resins and similar resins (viii) include, for example, polyethylene resins, polypropylene resins, copolymer resins of an olefin such as ethylene or propylene with another vinyl monomer, and acrylic resins.

Each of these thermoplastic resins can be used alone or in combination. Mixtures of these thermoplastic resins and copolymers of monomers constituting the same can also be used.

The thermoplastic resin is preferably such a thermoplastic resin as to satisfy the requirements in the physical properties of a toner image receiving layer comprising the thermoplastic resin in question and is more preferably such a thermoplastic resin that can satisfy, by itself, the requirements. It is also preferred that two or more resins exhibiting different physical properties as the toner image receiving layer are used in combination.

The thermoplastic resin preferably has a molecular weight larger than that of a thermoplastic resin used in the toner. However, this relationship in molecular weight between two thermoplastic resins may not be applied to some cases. For example, when the thermoplastic resin used in the toner image receiving layer has a softening point higher than that of the thermoplastic resin used in the toner, the former thermoplastic resin may preferably have a molecular weight equivalent to or lower than that of the latter thermoplastic resin.

A mixture of resins having the same composition but different average molecular weights is also preferably used as the thermoplastic resin. The relationship in molecular weight between the thermoplastic resin used in the toner image receiving layer and that used in the toner is preferably one disclosed in JP-A No. 08-334915.

The thermoplastic resin preferably has a particle size distribution larger than that of the thermoplastic resin used in the toner.

The thermoplastic resin preferably satisfies the requirements in physical properties as disclosed in, for example, JP-A No. 05-127413, No. 08-194394, No. 08-334915, No. 08-334916, No. 09-171265, and No. 10-221877.

The thermoplastic resin for use in the toner-image-receiving layer is typically preferably at least one of water-soluble resins, water-dispersible resins, and other aqueous resins for the following reasons (i) and (ii).

(i) These aqueous resins do not invite exhaustion of an organic solvent in a coating and drying process and are thereby environment friendly and have good workability.

(ii) Most of waxes and other releasing agents cannot be significantly dissolved in solvents at room temperature and are often dispersed in a medium (water or an organic solvent) before use. Such aqueous dispersions are more stable and suitable in production processes. When an aqueous composition containing the thermoplastic resin and a wax is applied, the wax readily bleeds out on the surface of a coated layer, thus yielding the effects of the releasing agent (anti-offset properties and adhesion resistance) more satisfactorily.

The aqueous resins are not specifically limited in their compositions, bonding configurations, molecular structures,

molecular weights, molecular weight distributions, shapes, and other factors and can be appropriately selected depending on an intended purpose, as long as they are water-soluble or water-dispersible resins. Examples of groups that impart hydrophilicity to polymers are sulfonic acid groups, hydroxyl groups, carboxyl groups, amino groups, amide groups, and ether groups.

Typical disclosure of the aqueous resins can be found in, for example, Research Disclosure No. 17,643, pp. 26; Research Disclosure No. 18,716, pp. 651; Research Disclosure No. 307,105, pp. 873-874; and JP-A No. 64-13546, pp. 71-75 (in Japanese).

Examples of such aqueous resins are vinylpyrrolidone-vinyl acetate copolymers, styrene-vinylpyrrolidone copolymers, styrene-maleic anhydride copolymers, water-soluble polyesters, water-soluble acrylics, water-soluble polyurethanes, water-soluble nylons (water-soluble polyamides), and water-soluble epoxy resins. Moreover, various types of gelatins may be selected according to the purpose from among liming gelatin, acid -treated gelatin and deliming gelatin wherein the content of calcium, etc., is reduced, and it is also preferable to use these in combination. Examples of water-soluble polyesters are various Pluscoats from Goo Chemical Co., Ltd. and the Finetex ES series from Dainippon Ink & Chemicals In. Examples of water-soluble acrylics are the Jurymer AT series from Nihon Junyaku Co., Ltd., Finetex 6161 and K-96 from Dainippon Ink & Chemicals Inc., and Hiros NL-1189 and BH-997L

from Seiko Chemical Industries Co., Ltd.

Examples of water dispersible resins are water-dispersible type resins such as water-dispersible acrylate resin, water-dispersible polyester resin, water-dispersible polystyrene resin and water-dispersible urethane resin; and emulsions such as acrylate resin emulsion, polyvinyl acetate emulsion and SBR (styrene butadiene) emulsion. The resin can be conveniently selected from an aqueous dispersion of the aforesaid thermoplastic resins (i) to (viii), their emulsions, or their copolymers, mixtures and cation-modified derivatives, and two or more sorts can be combined.

Examples of the aforesaid water-dispersible resins in the polyester class are the Vylonal Series from Toyobo Co., Ltd, the Pesresin A Series from Takamatsu Oil & Fat Co., Ltd., the Tuftone UE Series from Kao Corporation, the WR Series from Nippon Synthetic Chemical Industry Co., Ltd., and the Elitel Series from Unitika Ltd., and in the acrylic class are the Hiros XE, KE and PE series from Seiko Chemical Industries Co., Ltd., and the Jurymer ET series from Nihon Junyaku Co., Ltd.

It is preferred that the film-forming temperature (MFT) of the polymer is above room temperature for storage before printing, and is less than 100°C for fixing of toner particles.

The thermoplastic resin for use in the present invention is preferably a self-dispersible and water-dispersible polyester resin emulsion satisfying the following conditions (1) to (4). This type of

polyester resin emulsion is self-dispersible requiring no surfactant, is low in moisture absorbency even in an atmosphere at high humidity, exhibits less decrease in its softening point due to moisture and can thereby avoid offset in image-fixing and failures due to adhesion between sheets during storage. The emulsion is water-based and is environmentally friendly and excellent in workability. In addition, the polyester resin used herein readily takes a molecular structure with high cohesive energy. Accordingly, the resin has sufficient hardness (rigidity) during its storage but is melted with low elasticity and low viscosity during an image-fixing process for electrophotography, and the toner is sufficiently embedded in the toner-image-receiving layer to thereby form images having sufficiently high quality.

(1) The number-average molecular weight  $M_n$  is preferably from 5000 to 10000 and more preferably from 5000 to 7000.

(2) The molecular weight distribution ( $M_w/M_n$ ) is preferably 4 or less, and more preferably 3 or less, wherein  $M_w$  is the weight-average molecular weight.

(3) The glass transition temperature  $T_g$  is preferably from 40°C to 100°C and more preferably from 50°C to 80°C.

(4) The volume average particle diameter is preferably from 20nm to 200nm and more preferably from 40nm to 150nm.

The content of the thermoplastic resin in the toner-image-receiving layer is preferably from 10% by mass to 90% by mass, more preferably from 10% by mass to 70% by mass, and



further preferably from 20% by mass to 60% by mass.

- Releasing Agent -

The releasing agent can be at least one of silicone compounds, fluorine compounds, waxes, and matting agents. Among them, at least one selected from silicone oils, polyethylene waxes, carnauba waxes, silicone particles, and polyethylene wax particles is preferably used.

As the releasing agents, the compounds mentioned for example in "Properties and Applications of Waxes", Revised Edition, published by Saiwai Shobo, or The Silicon Handbook published by THE NIKKAN KOGYO SHIMBUN, may be used. Further, the silicon compounds, fluorine compounds or waxes used for the toners mentioned in JP-B Nos. 59-38581, 04-32380, Japanese Patent Nos. 2838498, 2949558, JP-A Nos. 50-117433, 52-52640, 57-148755, 61-62056, 61-62057, 61-118760, 02-42451, 03-41465, 04-212175, 04-214570, 04-263267, 05-34966, 05-119514, 06-59502, 06-161150, 06-175396, 06-219040, 06-230600, 06-295093, 07-36210, 07-43940, 07-56387, 07-56390, 07-64335, 07-199681, 07-223362, 07-287413, 08-184992, 08-227180, 08-248671, 08-248799, 08-248801, 08-278663, 09-152739, 09-160278, 09-185181, 09-319139, 09-319143, 10-20549, 10-48889, 10-198069, 10-207116, 11-2917, 11-44969, 11-65156, 11-73049 and 11-194542 can also be used. Moreover, two or more sets of these compounds can be used.

Examples of silicone compounds are non-modified silicone oils (specifically, dimethyl siloxane oil, methyl hydrogen silicone oil,

phenyl methyl-silicone oil, or products such as KF-96, KF-96L, KF-96H, KF-99, KF-50, KF-54, KF-56, KF-965, KF-968, KF-994, KF-995 and HIVAC F-4, F-5 from Shin-Etsu Chemical Co., Ltd.; SH200, SH203, SH490, SH510, SH550, SH710, SH704, SH705, SH7028A, SH7036, SM7060, SM7001, SM7706, SH7036, SH8710, SH1107 and SH8627 from Dow Corning Toray Silicone Co., Ltd.; and TSF400, TSF401, TSF404, TSF405, TSF431, TSF433, TSF434, TSF437, TSF450 Series, TSF451 series, TSF456, TSF458 Series, TSF483, TSF484, TSF4045, TSF4300, TSF4600, YF33 Series, YF-3057, YF-3800, YF-3802, YF-3804, YF-3807, YF-3897, XF-3905, XS69-A1753, TEX100, TEX101, TEX102, TEX103, TEX104, TSW831, from Toshiba Silicones), amino-modified silicone oils (e.g., KF-857, KF- 858, KF-859, KF-861, KF-864 and KF-880 from Shin-Etsu Chemical Co., Ltd., SF8417 and SM8709 from Dow Corning Toray Silicone Co., Ltd., and TSF4700, TSF4701, TSF4702, TSF4703, TSF4704, TSF4705, TSF4706, TEX150, TEX151 and TEX154 from Toshiba Silicones), carboxy-modified silicone oils (e.g., BY16-880 from Dow Corning Toray Silicone Co., Ltd., TSF4770 and XF42-A9248 from Toshiba Silicones), carbinol-modified silicone oils (e.g., XF42-B0970 from Toshiba Silicones), vinyl-modified silicone oils (e.g., XF40-A1987 from Toshiba Silicones), epoxy -modified silicone oils (e.g., SF8411 and SF8413 from Dow Corning Toray Silicone Co., Ltd.; TSF3965, TSF4730, TSF4732, XF42-A4439, XF42-A4438, XF42-A5041, XC96-A4462, XC96-A4463, XC96-A4464 and TEX170 from Toshiba Silicones), polyether-modified silicone oils (e.g., KF-351 (A), KF-352

(A), KF-353 (A), KF- 354 (A), KF-355 (A), KF-615(A), KF-618 and KF-945 (A) from Shin-Etsu Chemical Co., Ltd.; SH3746, SH3771, SF8421, SF8419, SH8400 and SF8410 from Dow Corning Toray Silicone Co., Ltd.; TSF4440, TSF4441, TSF4445, TSF4446, TSF4450, TSF4452, TSF4453 and TSF4460 from Toshiba Silicones), silanol-modified silicone oils, methacryl-modified silicone oils, mercapto-modified silicone oils, alcohol-modified silicone oils (e.g., SF8427 and SF8428 from Dow Corning Toray Silicone Co., Ltd., TSF4750, TSF4751 and XF42-B0970 from Toshiba Silicones), alkyl-modified silicone oils (e.g., SF8416 from Dow Corning Toray Silicone Co., Ltd., TSF410, TSF411, TSF4420, TSF4421, TSF4422, TSF4450, XF42-334, XF42-A3160 and XF42-A3161 from Toshiba Silicones), fluorine-modified silicone oils (e.g., FS1265 from Dow Corning Toray Silicone Co., Ltd., and FQF501 from Toshiba Silicones), silicone rubbers and silicone particulates (e.g., SH851, SH745U, SH55UA, SE4705U, SH502 UA&B, SRX539U, SE6770 U-P, DY 38-038, DY38-047, Trefil F-201, F-202, F-250, R-900, R-902A, E-500, E-600, E-601, E-506, BY29-119 from Dow Corning Toray Silicone Co., Ltd.; Tospal 105, 120, 130, 145, 240 and 3120 from Toshiba Silicones), silicone-modified resins (specifically, olefin resins or polyester resins, vinyl resins, polyamide resins, cellulosic resins, phenoxy resins, vinyl chloride-vinyl acetate resins, urethane resins, acrylate resins, styrene-acrylate resins and their copolymerization resins modified by silicone, e.g., Diaroma SP203V, SP712, SP2105 and SP3023 from Dainichiseika Color & Chemicals Mfg. Co., Ltd.; Modepa FS700,

FS710, FS720, FS730 and FS770 from NOF CORPORATION; Simac US-270, US-350, US-352, US-380, US- 413, US-450, Reseda GP-705, GS-30, GF-150 and GF-300 from TOAGOSEI CO., LTD.; SH997, SR2114, SH2104, SR2115, SR2202, DCI-2577, SR2317, SE4001U, SRX625B, SRX643, SRX439U, SRX488U, SH804, SH840, SR2107 and SR2115 from Dow Corning Toray Silicone Co., Ltd., YR3370, TSR1122, TSR102, TSR108, TSR116, TSR117, TSR125A, TSR127B, TSR144, TSR180, TSR187, YR47, YR3187, YR3224, YR3232, YR3270, YR3286, YR3340, YR3365, TEX152, TEX153, TEX171 and TEX172 from Toshiba Silicones), and reactive silicone compounds (specifically, addition reaction type, peroxide-curing type and ultraviolet radiation curing type, e.g., TSR1500, TSR1510, TSR1511, TSR1515, TSR1520, YR3286, YR3340, PSA6574, TPR6500, TPR6501, TPR6600, TPR6702, TPR6604, TPR6700, TPR6701, TPR6705, TPR6707, TPR6708, TPR6710, TPR6712, TPR6721, TPR6722, UV9300, UV9315, UV9425, UV9430, XS56-A2775, XS56-A2982, XS56- A3075, XS56-A3969, XS56-A5730, XS56-A8012, XS56-B1794, SL6100, SM3000, SM3030, SM3200 and YSR3022 from Toshiba Silicones).

Examples of fluorine compounds are fluorine oils (e.g., Daifluorol #1, # 3, #10, #20, #50, #100, Unidyne TG-440, TG-452, TG-490, TG- 560, TG-561, TG-590, TG-652, TG-670U, TG- 991, TG-999, TG-3010, TG-3020 and TG-3510 from Daikin Industries, Ltd.; MF-100, MF-110, MF-120, MF-130, MF-160 and MF-160E from Torchem Products; S-111, S-112, S-113, S-121, S-131, S-132, S-141 and S-145 from Asahi Glass Co., Ltd.; and, FC-430 and FC-431 from DU

PONT-MITSUI FLUOROCHEMICALS COMPANY,LTD), fluororubbers (e.g., LS63U from Dow Corning Toray Silicone Co., Ltd.), fluorine- modified resins (e.g., Modepa F220, F600, F2020, FF203, FF204 and F3035 from Nippon Oils and Fats; Diaroma FF203 and FF204 from Dainichiseika Color & Chemicals Mfg.Co.,Ltd.; Saflon S-381, S-383, S-393, SC-101, SC-105, KH-40 and SA-100 from Asahi Glass Co., Ltd.; E-351, EF-352, EF-801, EF-802, EF-601, TFEA, TFEMA and PDFOH from Torchem Products; and THV-200P from Sumitomo 3M), fluorine sulfonic acid compound (e.g., EF-101, EF-102, EF-103, EF- 104, EF-105, EF-112, EF-121, EF-122A, EF-122B, EF-122C, EF-123A, EF-123B, EF-125M, EF-132, EF-135M, EF-305, FBSA, KFBS and LFBS from Torchem Products), fluorosulfonic acid, and fluorine acid compounds or salts (specifically, anhydrous fluoric acid, dilute fluoric acid, fluoroboric acid, zinc fluoroborate, nickel fluoroborate, tin fluoroborate, lead fluoroborate, copper fluoroborate, fluorosilicic acid, fluorinated potassium titanate, perfluorocaprylic acid and ammonium perfluorooctanoate), inorganic fluorides (specifically, aluminum fluoride, potassium fluoride, fluorinated potassium zirconate, fluorinated zinc tetrahydrate, calcium fluoride, lithium fluoride, barium fluoride, tin fluoride, potassium fluoride, acid potassium fluoride, magnesium fluoride, fluorinated titanic acid, fluorinated zirconic acid, ammonium hexafluorinated phosphoric acid and potassium hexafluorinated phosphoric acid).

The waxes include, but are not limited to, synthetic

hydrocarbons, modified waxes, hydrogenated waxes, and naturally occurring waxes.

Examples of synthetic hydrocarbons are polyethylene waxes (e.g., Polylon A, 393 and H-481 from Chukyo Yushi Co., Ltd., and Sanwax E-310, E-330, E-250P, LEL-250, LEL-800 and LEL-400P from Sanyo Chemical Industries, Ltd. ), polypropylene waxes (e.g., Biscol 330-P, 550-P and 660-P from Sanyo Chemical Industries, Ltd. ), Fischertrops wax (e.g., FT100 and FT-0070 from Japan wax), and acid amide compounds or acid imide compounds (specifically, stearic acid amides and anhydrous phthalic imides such as Cellosol 920, B-495, high micron G-270, G-110 and hydrin D-757 from Chukyo Yushi Co., Ltd.).

Examples of modified waxes are amine-modified polypropylenes (e.g., QN-7700 from Sanyo Chemical Industries, Ltd.), acrylic acid-modified, fluorine-modified or olefin-modified waxes, urethane waxes (e.g., NPS-6010 and HAD-5090 from Japan Wax), and alcohol waxes (e.g., NPS-9210, NPS-9215, OX-1949 and XO-020T from Japan Wax).

Examples of hydrogenated waxes are castor oil (e.g., castor wax from Itoh Oil Chemicals Co., Ltd., castor oil derivatives (e.g., dehydrated castor oil DCO, DCO Z-1, DCO Z-3, castor oil fatty acid CO-FA, ricinoleic acid, dehydrated castor oil fatty acid DCO-FA, dehydrated castor oil fatty acid epoxy ester 4 ester, castor oil urethane acrylate CA-10, CA-20, CA-30, castor oil derivative MINERASOL S-74, S-80, S-203, S-42X, S-321, special castor oil

condensation fatty acid MINERASOL RC-2, RC-17, RC-55, RC-335, special castor oil condensation fatty acid ester MINERASOL LB-601, LB-603, LB-604, LB-702, LB-703, #11 and L-164 from Itoh Oil Chemicals Co., Ltd.), stearic acid (e.g., 12-hydroxystearic acid from Itoh Oil Chemicals Co., Ltd.), lauric acid, myristic acid, palmitic acid, behenic acid, sebacic acid (e.g., sebacic acid from Itoh Oil Chemicals Co., Ltd.), undecylenic acid (e.g., undecylenic acid from Itoh Oil Chemicals Co., Ltd.), heptyl acids (heptyl acids from Itoh Oil Chemicals Co., Ltd.), maleic acid, high grade maleic oils (e.g., HIMALEIN DC-15, LN-10, 00-15, DF-20 and SF-20 from Itoh Oil Chemicals Co., Ltd.), blown oils (e.g., selbonol #10, #30, #60, R-40 and S-7 from Itoh Oil Chemicals Co., Ltd.) and synthetic waxes such as cyclopentadieneic oils (CP oil and CP oil-S from Itoh Oil Chemicals Co., Ltd.).

Preferred examples of the naturally occurring waxes are vegetable waxes, animal waxes, mineral waxes, and petroleum waxes, of which vegetable waxes are typically preferred. When an aqueous thermoplastic resin is used as the thermoplastic resin in the toner-image-receiving layer, water-dispersible waxes are specifically preferred for their higher miscibility with the aqueous thermoplastic resin.

Examples of vegetable waxes are carnauba waxes (e.g., EMUSTAR AR-0413 from Japan Wax, and Cellosol 524 from Chukyo Yushi Co., Ltd.), castor oil (purified castor oil from Itoh Oil Chemicals Co., Ltd.), rape oil, soybean oil, Japan tallow, cotton wax,

rice wax, sugarcane wax, candelilla wax, Japan wax and jojoba oil. Among them, carnauba waxes having a melting point of 70°C to 95°C are preferred, since the resulting image-receiving sheet has excellent anti-offset properties and adhesion resistance, can pass through a machine smoothly, has good glossiness, invites less cracking and can form high-quality images.

The animal waxes include, but are not limited to, beeswaxes, lanolin, spermaceti waxes, whale oils, and wool waxes.

Examples of mineral waxes are natural waxes such as montan wax, montan ester wax, ozokerite and ceresin, or fatty acid esters (Sansosizer-DOA, AN-800, DINA, DIDA, DOZ, DOS, TOTM, TITM, E-PS, nE-PS, E-PO, E-4030, E-6000, E-2000H, E-9000H, TCP and C-1100, New Japan Chemical Co., Ltd.). Among them, montan waxes having a melting point of 70°C to 95°C are preferred, since the resulting image-receiving sheet has excellent anti-offset properties and adhesion resistance, can pass through a machine smoothly, has good glossiness, invites less cracking and can form high-quality images.

Preferred examples of petroleum waxes may for example be a paraffin wax (e.g., Paraffin wax 155, 150, 140, 135, 130, 125, 120, 115, HNP-3, HNP-5, HNP- 9, HNP-10, HNP-11, HNP-12, HNP-14G, SP-0160, SP-0145, SP-1040, SP-1035, SP-3040, SP-3035, NPS-8070, NPS-L -70, OX-2151, OX-2251, EMUSTAR-0384 and EMUSTAR-0136 from Japan Wax; Cellosol 686, 428, 651-A, A, H-803, B-460, E- 172, 866, K-133, hydrin D-337 and E-139 from Chukyo Yushi Co., Ltd.;



125 paraffin, 125° FD, 130° paraffin, 135° paraffin, 135° H, 140° paraffin, 140° N, 145° paraffin and paraffin wax M from Nisseki Mitsubishi Petroleum), or a microcrystalline wax (e.g., Hi-Mic-2095, Hi-Mic-3090, Hi-Mic-1080, Hi-Mic-1070, Hi-Mic-2065, Hi-Mic-1045, Hi-Mic-2045, EMUSTAR-0001 and EMUSTAR-042X from Japan Wax; Cellosol 967, M, from Chukyo Yushi Co., Ltd.; 55 Microwax and 180 Microwax from Nisseki Mitsubishi Petroleum ), and petrolatum (e.g., OX-1749, OX-0450, OX-0650B, OX-0153, OX-261BN, OX-0851, OX- 0550, OX-0750B, JP-1500, JP-056R and JP-011P from Japan Wax).

The content of the naturally occurring wax in the toner-image-receiving layer (surface layer) is preferably from 0.1g/m<sup>2</sup> to 4g/m<sup>2</sup>, and more preferably from 0.2g/m<sup>2</sup> to 2g/m<sup>2</sup>.

If the content is less than 0.1 g/m<sup>2</sup>, sufficient anti-offset properties and adhesion resistance may not be obtained. If it exceeds 4 g/m<sup>2</sup>, the resulting images may decreased quality due to excessive wax.

To obtain satisfactory anti-offset properties and to allow the sheet to pass through a machine smoothly, the melting point of the naturally occurring wax is preferably from 70°C to 95°C, and more preferably from 75°C to 90°C.

The matting agents include various conventional matting agents. Solid particles for use in the matting agents can be classified as inorganic particles (inorganic matting agents) and organic particles (organic matting agents).

Specifically, inorganic matting agents may be oxides (for example, silicon dioxide, titanium oxide, magnesium oxide, aluminum oxide), alkaline earth metal salts (for example, barium sulfate, calcium carbonate, magnesium sulfate), silver halides (for example, silver chloride or silver bromide), and glass.

Examples of inorganic matting agents are given for example in West German Patent No. 2529321, UK Patent Nos. 760775, 1260772, and US Patent Nos. 1201905, 2192241, 3053662, 3062649, 3257206, 3322555, 3353958, 3370951, 3411907, 3437484, 3523022, 3615554, 3635714, 3769020, 4021245 and 4029504.

The aforesaid organic matting agent contains starch, cellulose ester (for example, cellulose-acetate propionate), cellulose ether (for example, ethyl cellulose) and a synthetic resin. It is preferred that the synthetic resin is insoluble or difficultly soluble. Examples of insoluble or difficultly soluble synthetic resins include poly(meth)acrylic esters, e.g., polyalkyl(meth)acrylate and polyalkoxyalkyl(meth)acrylate, polyglycidyl(meth)acrylate), poly(meth)acrylamide, polyvinyl esters (e.g., polyvinyl acetate), polyacrylonitrile, polyolefins (e.g., polyethylene), polystyrene, benzoguanamine resin, formaldehyde condensation polymer, epoxy resins, polyamides, polycarbonates, phenolic resins, polyvinyl carbazole and polyvinylidene chloride. Copolymers which combine the monomers used in the above polymers, may also be used.

In the case of the aforesaid copolymers, a small amount of

hydrophilic repeating units may be included. Examples of monomers which form a hydrophilic repeating unit are acrylic acid, methacrylic acid,  $\alpha$ ,  $\beta$ -unsaturated dicarboxylic acid, hydroxyalkyl(meth)acrylate, sulfoalkyl (meth)acrylate and styrene sulfonic acid.

Examples of organic matting agents are for example given in UK Patent No. 1055713, US Patent Nos. 1939213, 2221873, 2268662, 2322037, 2376005, 2391181, 2701245, 2992101, 3079257, 3262782, 3443946, 3516832, 3539344, 3591379, 3754924 and 3767448, and JP-A Nos. 49-106821, 57-14835.

Also, two or more types of solid particles may be used in conjunction as matting agents. The average particle size of the solid particles may conveniently be, for example, 1 $\mu$ m to 100 $\mu$ m, but is preferably 4 $\mu$ m to 30 $\mu$ m. The usage amount of the solid particles may conveniently be 0.01g/m<sup>2</sup> to 0.5g/m<sup>2</sup>, but is preferably 0.02g/m<sup>2</sup> to 0.3g/m<sup>2</sup>.

The releasing agents for use in the toner-image-receiving layer can also be derivatives, oxides, purified products, and mixtures of the aforementioned substances. These releasing agents may each have a reactive substituent.

To obtain satisfactory anti-offset properties and to allow the sheet to pass through a machine smoothly, the melting point of the releasing agent is preferably from 70°C to 95°C, and more preferably from 75°C to 90°C.

When an aqueous thermoplastic resin is used as the

thermoplastic resin in the toner-image-receiving layer, water-dispersible releasing agents are specifically preferred for higher miscibility with the aqueous thermoplastic resin.

The content of the releasing agent in the toner-image-receiving layer is preferably from 0.1% by mass to 10% by mass, more preferably from 0.3% by mass to 8.0% by mass, and further preferably from 0.5% by mass to 5.0% by mass.

- Other components -

The other components include additives for improving the thermodynamic properties of the toner-image-receiving layer. Examples of such additives are coloring agents, plasticizers, fillers, crosslinking agents, charge control agents, emulsions, and dispersions.

Examples of coloring agents are optical whitening agents, white pigments, colored pigments and dyes.

The aforesaid optical whitening agent has absorption in the near-ultraviolet region, and is a compound which emits fluorescence at 400 to 500nm. The various optical whitening agents known in the art may be used without any particular limitation. As this optical whitening agent, the compounds described in "The Chemistry of Synthetic Dyes" Volume V, Chapter 8 edited by K. V. Venkataratnam can conveniently be mentioned. Specific examples are stilbene compounds, coumarin compounds, biphenyl compounds, benzo-oxazoline compounds, naphthalimide compounds, pyrazoline compounds and carbostyryl compounds.

Examples of these are white furfar-PSN, PHR, HCS, PCS, B from Sumitomo Chemicals, and UVITEX-OB from Ciba-Geigy.

Examples of white pigments are the inorganic pigments (e.g., titanium oxide, calcium carbonate, etc.).

Examples of organic pigments are various pigments and azo pigments described in JP-A No. 63-44653, (e.g., azo lakes such as carmine 6B and red 2B, insoluble azo compounds such as mono-azo yellow, pyrazolo orange and Balkan orange, and condensed azo compounds such as chromophthal yellow and chromophthal red), polycyclic pigments (e.g., phthalocyanines such as copper phthalocyanine blue and copper phthalocyanine green), thioxadines such as thioxadine violet, isoindolinones such as isoindolinone yellow, surenes such as perylene, perinon, hulavanthoron and thioindigo, lake pigments (e.g., Malachite Green, Rhodamine B, Rhodamine G and Victoria Blue B), and inorganic pigments (e.g., oxides, titanium dioxide and red ocher, sulfates such as precipitated barium sulfate, carbonates such as precipitated calcium carbonates, silicates such as water-containing silicates and anhydrous silicates, metal powders such as aluminum powder, bronze powder and zinc dust, carbon black, chrome yellow and Berlin blue).

One of these may be used alone, or two or more may be used in conjunction. Of these, titanium oxide is particularly preferred as the pigment.

There is no particular limitation on the form of the pigment, but hollow particles are preferred from the viewpoint that they have

excellent heat conduction properties (low heat conduction properties) during image fixing.

The various dyes known in the art may be used as the aforesaid dye.

Examples of oil-soluble dyes are anthraquinone compounds and azo compounds.

Examples of water-insoluble dyes are vat dyes such as C.I. Vat violet 1, C.I. Vat violet 2, C.I. Vat violet 9, C.I. Vat violet 13, C.I. Vat violet 21, C.I. Vat blue 1, C.I. Vat blue 3, C.I. Vat blue 4, C.I. Vat blue 6, C.I. Vat blue 14, C.I. Vat blue 20 and C.I. Vat blue 35, disperse dyes such as C.I. disperse violet 1, C.I. disperse violet 4, C.I. disperse violet 10, C.I. disperse blue 3, C.I. disperse blue 7 and C.I. disperse blue 58, and oil-soluble dyes such as C. I. solvent violet 13, C.I. solvent violet 14, C.I. solvent violet 21, C.I. solvent violet 27, C.I. solvent blue 11, C.I. solvent blue 12, C.I. solvent blue 25 and C.I. solvent blue 55.

Colored couplers used in silver halide photography may also be used to advantage.

The amount of coloring agent in the aforesaid toner-image-receiving layer (surface) is preferably  $0.1\text{g}/\text{m}^2$  to  $8\text{g}/\text{m}^2$ , but more preferably  $0.5\text{g}/\text{m}^2$  to  $5\text{g}/\text{m}^2$ .

If the amount of coloring agent is less than  $0.1\text{g}/\text{m}^2$ , the light transmittance in the toner-image-receiving layer is high, and if the amount of the aforesaid coloring agent exceeds  $8\text{g}/\text{m}^2$ , handling becomes more difficult due to cracks, and adhesion resistance.

Among these coloring agents, the amount of the pigment is preferably less than 40% by mass, more preferably less than 30% by mass, and further preferably less than 20% by mass based on the mass of the thermoplastic resin constituting the toner-image-receiving layer.

The plasticizers can be any of known plasticizers for resins. The plasticizers serve to control fluidizing or softening of the toner image receiving layer by action of heat and/or pressure when the toner is fixed.

Typical disclosures of the plasticizers can be found in, for example, Kagaku Binran (Chemical Handbook), ed. by The Chemical Society of Japan, Maruzen Co., Ltd. Tokyo; Plasticizer, Theory and Application, edited and written by Koichi Murai and published by Saiwai Shobo; Volumes 1 and 2 of Studies on Plasticizer, edited by Polymer Chemistry Association; and Handbook on Compounding Ingredients for Rubbers and Plastics, edited by Rubber Digest Co.

Examples of the plasticizers include, for example, esters of the following acids; phthalic, phosphoric, fatty acids, abietic, adipic, sebacic, azelaic, benzoic, butyric, epoxidized fatty acids, glycolic, propionic, trimellitic, citric, sulfonic, carboxylic, succinic, maleic, fumaric, and stearic acid; amides including aliphatic amides and sulfonamides, ethers, alcohols, lactones, poly (ethylene oxide) s (refer to JP-A No. 59-83154, No. 59-178451, No. 59-178453, No. 59-178454, No. 59-178455, No. 59-178457, No. 62-174754, No.

62-245253, No. 61-209444, No. 61-200538, No. 62-8145, No. 62-9348, No. 62-30247, No. 62-136646, and No. 2-235694). The plasticizers can be used by mixing with the resins.

Polymer plasticizers having a relatively low molecular weight can also be used herein. The molecular weight of such a plasticizer is preferably lower than that of a resin to be plasticized and is preferably 15000 or less, and more preferably 5000 or less. When these polymer plasticizers are used, those of the same kind with the resin to be plasticized are preferred. For example, low-molecular-weight polyesters are preferably used for plasticizing a polyester resin. In addition, oligomers can be used as the plasticizers. In addition to the aforementioned compounds, the plasticizers are also commercially available under the trade names of, for example, Adekacizer PN-170 and PN-1430 from Asahi Denka Kogyo Co., Ltd.; PARAPLEX G-25, G-30 and G-40 from C. P. Hall Co.; Ester Gum 8L-JA, Ester R-95, Pentalin 4851, FK 115, 4820 and 830, Luisol 28-JA, Picolastic A75, Picotex LC and Crystalex 3085 from Rika Hercules Co.

The plasticizer can be freely used so as to mitigate stress and/or strain when the toner particles are embedded in the toner-image-receiving layer. Such strain includes, for example, physical strain such as elastic force and viscosity, and strain due to material balance in, for example, molecules, principle chains and/or pendant moieties of the binder.

The plasticizer may be finely dispersed, may undergo



micro-phase separation into islands-in-sea structure or may be sufficiently dissolved or miscible with other components such as a binder in the layers.

The content of the plasticizer in the toner-image-receiving layer is preferably from 0.001% by mass to 90% by mass, more preferably from 0.1% by mass to 60% by mass, and further preferably from 1% by mass to 40% by mass.

The plasticizers can be used to control the slipping property leading to the improvement in the transport performance due to friction reduction, improve the anti-offset property during fixing (detachment of toner or layers onto the fixing means) or control the curling property and the charging property for a desirable latent toner image formation.

The filler may be an organic or inorganic filler, and reinforcers for binder resins, bulking agents and reinforcements known in the art may be used.

This filler may be selected by referring to "Handbook of Rubber and Plastics Additives" (ed. Rubber Digest Co.), "Plastics Blending Agents - Basics and Applications" (New Edition) (Taisei Co.) and "The Filler Handbook" (Taisei Co.).

As the filler, various inorganic fillers (or pigments) can be used. Examples of inorganic pigments are silica, alumina, titanium dioxide, zinc oxide, zirconium oxide, micaceous iron oxide, white lead, lead oxide, cobalt oxide, strontium chromate, molybdenum pigments, smectite, magnesium oxide, calcium oxide, calcium

carbonate and mullite. Silica and alumina are particularly preferred. One of these fillers may be used alone, or two or more may be used in conjunction. It is preferred that the filler has a small particle diameter. If the particle diameter is large, the surface of the toner-image-receiving layer tends to become rough.

Silica includes spherical silica and amorphous silica. The silica may be synthesized by the dry method, wet method or aerogel method. The surface of the hydrophobic silica particles may also be treated by trimethylsilyl groups or silicone. Colloidal silica is preferred. The average mean particle diameter of the silica is preferably 4nm to 120nm, but more preferably 4nm to 90nm.

The silica is preferably porous. The average pore size of porous silica is preferably 50nm to 500nm. Also, the average pore volume per mass of porous silica is preferably 0.5ml/g to 3 ml/g, for example.

Alumina includes anhydrous alumina and hydrated alumina. Examples of crystallized anhydrous aluminas which may be used are  $\alpha$ ,  $\beta$ ,  $\gamma$ ,  $\delta$ ,  $\xi$ ,  $\eta$ ,  $\theta$ ,  $\kappa$ ,  $\rho$  or  $\chi$ . Hydrated alumina is preferred to anhydrous alumina. The hydrated alumina may be a monohydrate or trihydrate. Monohydrates include pseudo-boehmite, boehmite and diaspora. Trihydrates include gypsite and bayerite. The average particle diameter of alumina is preferably 4nm to 300nm, but more preferably 4nm to 200nm. Porous alumina is preferred. The average pore size of porous alumina is preferably 50nm to 500nm. The average pore volume per mass of porous alumina is of

the order of 0.3ml/g to 3ml/g.

The alumina hydrate can be synthesized by the sol-gel process wherein ammonia is added to an aluminum salt solution to precipitate alumina, or by hydrolysis of an alkali aluminate.

Anhydrous alumina can be obtained by dehydrating alumina hydrate by the action of heat.

It is preferred that the filler is 5 parts by mass to 2000 parts by mass, relative to the dry mass of the binder in the toner image-receiving layer where the filler is to be added.

A crosslinking agent can be added in order to adjust the storage stability or thermoplastic properties of the toner-image-receiving layer. Examples of this crosslinking agent are compounds containing two or more reactive groups in the molecule such as epoxy, isocyanate, aldehyde, active halogen, active methylene, acetylene and other reactive groups known in the art.

The crosslinking agent may also be a compound having two or more groups able to form bonds such as hydrogen bonds, ionic bonds or coordination bonds.

The crosslinking agent may be a compound known in the art such as a resin coupling agent, curing agent, polymerizing agent, polymerization promoter, coagulant, film-forming agent or film-forming assistant. Examples of coupling agents are chlorosilanes, vinylsilanes, epoxysilanes, aminosilanes, alkoxyaluminum chelates, titanate coupling agents or other agents known in the art such as those mentioned in "Handbook of Rubber

and Plastics Additives" (ed. Rubber Digest Co.).

The charge control agents can be used for controlling transfer and attachment of the toner, and for preventing adhesion of the image-receiving sheet due to charging.

The charge control agent may be any charge control agent known in the art, i.e., surfactants such as cationic surfactants, anionic surfactants, amphoteric surfactants, non-ionic surfactants, and polymer electrolytes or electroconducting metal oxides.

Examples of the surfactants are cationic charge inhibitors such as quarternary ammonium salts, polyamine derivatives, cation-modified polymethylmethacrylate, cation-modified polystyrene, anionic charge inhibitors such as alkyl phosphates and anionic polymers, or non-ionic charge inhibitors such as polyethylene oxide. When the toner has a negative charge, cationic charge inhibitors and non-ionic charge inhibitors are preferred.

Examples of electroconducting metal oxides are ZnO, TiO<sub>2</sub>, SnO<sub>2</sub>, Al<sub>2</sub>O<sub>3</sub>, In<sub>2</sub>O<sub>3</sub>, SiO<sub>2</sub>, MgO, BaO and MoO<sub>3</sub>. These electroconducting metal oxides may be used alone, or they may be used in the form of a complex oxide.

Also, the electroconducting metal oxide may contain other elements, for example ZnO may contain Al or In, TiO<sub>2</sub> may contain Nb or Ta, and SnO<sub>2</sub> may contain Sb, Nb or halogen elements (doping).

The materials used to obtain the toner-image-receiving layer of the present invention may also contain various additives to

improve stability of the output image or improve stability of the toner-image-receiving layer itself. Examples of additives are antioxidants, age resistors, degradation inhibitors, anti-ozone degradation inhibitors, ultraviolet light absorbers, metal complexes, light stabilizers or preservatives.

Examples of antioxidants are chroman compounds, coumarane compounds, phenol compounds (e.g., hindered phenols), hydroquinone derivatives, hindered amine derivatives and spiroindan compounds. Antioxidants are given for example in JP-A No. 61-159644.

Examples of age resistors are given in "Handbook of Rubber and Plastics Additives", Second Edition (1993, Rubber Digest Co.), pp. 76-121.

Examples of ultraviolet light absorbers are benzotriazo compounds (US Patent No. 3533794), 4-thiazolidone compounds (US Patent No. 3352681), benzophenone compounds (JP-A No. 46-2784) and ultraviolet light absorbing polymers (JP-A No. 62-260152).

Examples of metal complexes are given in US Patent Nos. 4241155, 4245018, 4254195, and JP-A Nos. 61-88256, 62-174741, 63-199248, 01-75568, 01-74272.

Photographic additives known in the art may also be added to the material used to obtain the toner-image-receiving layer as described above. Examples of photographic additives are given in the Journal of Research Disclosure (hereafter referred to as RD) No.

17643 (December 1978), No. 18716 (November 1979) and No. 307105 (November 1989), the relevant sections being summarised below.

Type of additive	RD17643	RD18716	RD307105
1. Whitener	p24	p648, right-hand column	p868
2. Stabilizer	pp.24-25	p649, right-hand column	pp.868-870
3. Light absorbers (ultraviolet ray absorbers)	pp. 25-26	p649, right-hand column	p873
4. Pigment image stabilizers	p25	p650, right-hand column	p872
5. Film-hardening agents	p26	p651, left-hand column	pp.874-875
6. Binders	p26	p651, left-hand column	pp.873-874
7. Plasticizers, lubricants	p27	p650, right-hand column	p876
8. Coating assistants (surfactants)	pp.26-27	p650, right-hand column	pp.875-876
9. Antistatic agents	p27	p650, right-hand column	pp.867-877
10. Matting agents			pp.878-879

The toner-image-receiving layer of the present invention is prepared by applying a coating composition containing a polymer for use in the toner-image-receiving layer using, for example, a wire

coater, and drying the coated layer. The coating composition is prepared, for example, by dissolving or homogeneously dispersing a thermoplastic polymer, and additives such as a plasticizer in an organic solvent such as alcohols and ketones. Organic solvents for use herein include, but are not limited to, methanol, isopropyl alcohol, and methyl ethyl ketone. If the polymer for use in the toner-image-receiving layer is soluble in water, the toner-image-receiving layer can be prepared by applying an aqueous solution of the polymer onto the support. If not, the toner-image-receiving layer can be prepared by applying an aqueous dispersion of the polymer onto the support.

The film-forming temperature of the polymer for use in the present invention is preferably room temperature or higher for better storage before printing, and is preferably 100°C or lower for better image-fixing of the toner particles.

The toner-image-receiving layer may be prepared by applying a coating liquid containing a polymer for use in the toner-image-receiving layer onto the support using, for example, a wire coater, and drying the coated layer. The coating liquid is prepared, for example, by dissolving or homogeneously dispersing a thermoplastic polymer and additives such as a plasticizer in an organic solvent such as an alcohol or a ketone. Organic solvents for use herein include, but are not limited to, methanol, isopropyl alcohol, and methyl ethyl ketone. When the polymer for use in the toner-image-receiving layer is soluble in water, the

toner-image-receiving layer can be prepared by applying an aqueous solution of the polymer onto the support. If not, the toner-image-receiving layer can be prepared by applying an aqueous dispersion of the polymer onto the support.

The film-forming temperature of the polymer is preferably room temperature or higher for better storage before printing, and is preferably 100°C or lower for better fixing of the toner particles.

The toner-image-receiving layer of the present invention is coated so that the coating mass after drying is for example 1g/m<sup>2</sup> to 20g/m<sup>2</sup>, but preferably 4g/m<sup>2</sup> to 15g/m<sup>2</sup>.

[Physical Properties of Toner-image-receiving layer]

The 180-degree peel strength of the toner-image-receiving layer with a fixing member is preferably 0.1 N/25-mm or less, and more preferably 0.041 N/25-mm or less at an image-fixing temperature. The 180-degree peel strength can be determined according to a method specified in JIS K 6887 using a surface material of the fixing member.

It is preferred that the toner-image-receiving layer has a high degree of whiteness. This whiteness is measured by the method specified in JIS P 8123, and is preferably 85% or more. It is preferred that the spectral reflectance is 85% or more in the wavelength region of 440nm to 640nm, and that the difference between the maximum spectral reflectance and minimum spectral reflectance in this wavelength range is within 5%. Further, it is preferred that the spectral reflectance is 85% or more in the



wavelength region of 400nm to 700nm, and that the difference between the maximum spectral reflectance and minimum spectral reflectance in this wavelength range is within 5%.

Specifically, regarding the whiteness, the  $L^*$  value is preferably 80 or higher, preferably 85 or higher and still more preferably 90 or higher in a CIE 1976 ( $L^*a^*b^*$ ) color space. The tone of the white color should preferably be as neutral as possible. Regarding the whiteness tone, the value of  $(a^*)^2 + (b^*)^2$  is preferably 50 or less, more preferably 18 or less and still more preferably 5 or less in a ( $L^*a^*b^*$ ) space.

It is preferred that the toner-image-receiving layer has high gloss. The gloss is 45, preferably 60 or higher, more preferably 75 or higher and still more preferably 90 or higher over the whole range from white where there is no toner, to black where there is maximum density.

However, the gloss is preferably less than 110. If it exceeds 110, the image has a metallic appearance which is undesirable.

Gloss may be measured based on JIS Z 8741.

It is preferred that the toner-image-receiving layer has a high smoothness. The arithmetic mean roughness ( $R_a$ ) is preferably  $3\mu\text{m}$  or less, more preferably  $1\mu\text{m}$  or less and still more preferably  $0.5\mu\text{m}$  or less over the whole range from white where there is no toner, to black where there is maximum density.

Arithmetic mean roughness may be measured based on JIS B 0601, JIS B 0651 and JIS B 0652.

It is preferred that the toner-image-receiving layer has one of the following physical properties, more preferred that it has several of the following physical properties, and most preferred that it has all of the following physical properties.

(1) The melting temperature  $T_m$  of the toner-image-receiving layer is preferably  $30^{\circ}\text{C}$  or higher and  $[(T_m \text{ of the toner}) + 20^{\circ}\text{C}]$  or lower.

(2) The temperature at which the viscosity of the toner-image-receiving layer is  $1 \times 10^5$  CP is  $40^{\circ}\text{C}$  or higher and lower than that of the toner.

(3) The storage modulus  $G'$  of the toner-image-receiving layer is preferably from  $1 \times 10^2$  Pa to  $1 \times 10^5$  Pa and the loss modulus  $G''$  thereof is preferably from  $1 \times 10^2$  Pa to  $1 \times 10^5$  Pa at an image-fixing temperature.

(4) The loss tangent  $G''/G'$  as the ratio of the loss modulus  $G''$  to the storage modulus  $G'$  of the toner-image-receiving layer at an image-fixing temperature is preferably from 0.01 to 10.

(5) The storage modulus  $G'$  of the toner-image-receiving layer at an image-fixing temperature preferably falls in a range of -50 to +2500 of the storage modulus  $G''$  of the toner at the image-fixing temperature.

(6) A melted toner forms an inclination with the toner-image-receiving layer of preferably 50 degrees or less and more preferably 40 degrees or less.

The toner-image-receiving layer preferably also satisfies the

physical properties given in Japanese Patent No. 2788358, and JP-A Nos. 07-248637, 08-305067 and 10-239889.

It is preferred that the surface electrical resistance of the toner-image-receiving layer is within the range of  $1 \times 10^6 \Omega/\text{cm}^2$  to  $1 \times 10^{15} \Omega/\text{cm}^2$  (under conditions of 25°C, 65% RH).

If the surface electrical resistance is less than  $1 \times 10^6 \Omega/\text{cm}^2$ , the toner amount transferred to the toner-image-receiving layer is insufficient, and the density of the toner image obtained may be too low. On the other hand, if the surface electrical resistance exceeds  $1 \times 10^{15} \Omega/\text{cm}^2$ , more charge than necessary is produced during transfer, toner is transferred insufficiently, image density is low and static electricity develops causing dust to adhere during handling of the image-receiving sheet for electrophotography, or misfeed, overfeed, discharge marks or toner transfer dropout may occur.

Also, the surface electrical resistance of the surface on the opposite side of the carrier to the toner-image-receiving layer is preferably  $5 \times 10^8 \Omega/\text{cm}^2$  to  $3.2 \times 10^{10} \Omega/\text{cm}^2$ , and more preferably  $1 \times 10^9 \Omega/\text{cm}^2$  to  $1 \times 10^{10} \Omega/\text{cm}^2$ .

The aforesaid surface electrical resistances were measured based on JIS K 6911. The sample was left with air-conditioning for 8 hours or more at a temperature of 20°C and humidity 65%. Measurements were made using an Advantest Ltd. R8340 under the same environmental conditions after passing a current for 1 minute at an applied voltage of 100V.

In the image-receiving sheet for electrophotography, other

layers other than the toner-image-receiving layer may for example include a surface protective layer, interlayer, back layer, adhesion improving layer, undercoat layer, cushion layer, charge regulating (inhibiting) layer, reflecting layer, toner adjusting layer, storage improving layer, anti-sticking layer, anti-curl layer and smoothing layer. These layers may be used alone, or two or more may be used in combination.

There is no particular limitation on the thickness of the electrophotographic image-receiving sheet of the present invention, which may be suitably selected according to the purpose, but it is for example preferably 50 $\mu$ m to 350 $\mu$ m, and more preferably 100 $\mu$ m to 280 $\mu$ m.

The surface protective layer may be arranged on the surface of the toner-image-receiving layer in order to protect the surface, to improve the storage stability, to improve the handleability, to impart writability to the sheet, to enable the sheet to pass through an apparatus more smoothly, and to impart anti-offset performance to the sheet. The surface protective layer can be a single layer or a multilayer. It may comprise any of thermoplastic resins, thermosetting resins, and other resins as a binder and preferably comprises a resin or polymer of the same type with that in the toner-image receiving layer. The thermodynamic properties, electrostatic properties, and other properties of the surface protective layer are not necessary to be the same with those of the toner-image-receiving layer and can be optimized, respectively.

The surface protective layer may comprise any of additives which can be used in the toner-image-receiving layer. In particular, the surface protective layer preferably comprises, in addition to the releasing agent, other additives such as a matting agent. Such matting agents can be those conventionally used.

The outermost surface (e.g., the surface protective layer, if any) of the electrophotographic image-receiving sheet is preferably satisfactorily miscible or compatible with the toner for better image-fixing properties. More specifically, the contact angle between the outermost surface and a fused toner is preferably from 0 degree to 40 degrees.

The back layer (backside layer) is preferably arranged on the back side (an opposite side to the toner-image-receiving layer) of the electrophotographic image-receiving sheet in order to enable the back side to receive images, to improve the quality of the images formed on the back side, to improve curling balance, and/or to enable the sheet to pass through an apparatus more smoothly.

The color of the back layer is not specifically limited. When the electrophotographic image-receiving sheet is an image-receiving sheet capable of receiving images on both sides, the back layer is preferably white. The back layer preferably has a whiteness and a spectroscopic reflectance of 85% or more as in the front side (the toner-image-receiving layer side).

The back layer may have the same configuration as the toner-image-receiving layer in order to enable the both sides to

receive or form images more satisfactorily. The back layer may further comprise any of the aforementioned additives, of which matting agents, and charge control agents are preferably used. The back layer can be a single layer or a multilayer.

When a releasing oil is used in a fixing roller and other members to prevent offset during the image-fixing, the back layer is preferably capable of absorbing oils.

The adhesion improving layer is preferably arranged in the electrophotographic image-receiving sheet to improve adhesion between the support and the toner-image-receiving layer. The adhesion improving layer may comprise any of the aforementioned additives, of which crosslinking agents are preferably used. The electrophotographic image-receiving sheet may have a cushioning layer between the adhesion improving layer and the toner-image-receiving layer to enable the sheet to receive the toner more satisfactorily.

The interlayer may be arranged, for example, between the support and adhesion improving layer, between the adhesion improving layer and the cushioning layer, between the cushioning layer and the toner-image-receiving layer, and/or between the toner-image-receiving layer and the storage stability improving layer. When the electrophotographic image-receiving sheet comprises the support, the toner-image-receiving layer, and the interlayer, the interlayer can be arranged, for example, between the support and the toner-image-receiving layer.

### <Toner>

In the electrophotographic image-receiving sheet of the present invention, the toner-image-receiving layer receives toner during printing or copying.

The toner contains at least a binder resin and a coloring agent, but may contain releasing agents and other components as necessary.

#### - Toner binder resin -

Examples of the toner binder resin are styrenes such as styrene or parachlorostyrene; vinyl esters such as vinyl naphthalene, vinyl chloride, vinyl bromide, vinyl fluoride, vinyl acetate, vinyl propionate, vinyl benzoate and vinyl butyrate; methylene aliphatic carboxylates such as methyl acrylate, ethyl acrylate, n-butyl acrylate, isobutyl acrylate, dodecyl acrylate, n-octyl acrylate, 2-chloroethyl acrylate, phenyl acrylate, methyl  $\alpha$ -chloroacrylate, methyl methacrylate, ethyl methacrylate and butyl acrylate; vinyl nitriles such as acrylonitrile, methacrylonitrile and acrylamide; vinyl ethers such as vinyl methyl ether, vinyl ethyl ether and vinyl isobutyl ether; N-vinyl compounds such as N-vinyl pyrrole, N-vinylcarbazole, N-vinyl indole and N-vinyl pyrrolidone; and vinyl carboxylic acids such as methacrylic acid, acrylic acid and cinnamic acid. These vinyl monomers may be used alone, or their copolymers may be used. In addition, various polyesters may be used, and various waxes may be used in conjunction.

Of these resins, it is preferable to use a resin of the same type

as the resin used for the toner image-receiving television layer of the present invention.

- Toner coloring agents -

The coloring agents generally used in the art can be used without limitation. Examples are carbon black, chrome yellow, Hanzer yellow, benzidine yellow, thuren yellow, quinoline yellow, permanent orange GTR, pyrazolone orange, Balkan orange, watch young red, permanent red, brilliant carmin 3B, brilliant carmin 6B, dippon oil red, pyrazolone red, lithol red, rhodamine B lake, lake red C, rose bengal, aniline blue, ultramarine blue, chalco oil blue, methylene blue chloride, phthalocyanine blue, phthalocyanine green and malachite green oxalate. Various dyes may also be added such as acridine, xanthene, azo, benzoquinone, azine, anthraquinone, thioindigo, dioxadine, thiadine, azomethine, indigo, thioindigo, phthalocyanine, aniline black, polymethane, triphenylmethane, diphenylmethane, thiazine, thiazole and xanthene. These coloring agents may be used alone, or plural coloring agents may be used together.

It is preferred that the amount of coloring agent is within the range of 2% by mass to 8 % by mass. If the amount of coloring agent is more than 2 % by mass, the coloration does not become weaker, and if it is less than 8 % by mass, transparency is not lost.

- Toner releasing agent -

The releasing agent may in principle be any of the waxes known in the related art, but polar waxes containing nitrogen such



as highly crystalline polyethylene wax of relatively low molecular weight, Fischertropsch wax, amide wax and urethane wax are particularly effective. For polyethylene wax, it is particularly effective if the molecular weight is less than 1000, but a range of 300 to 1000 is more preferred.

Compounds containing urethane bonds have a solid state due to the strength of the cohesive force of the polar groups even if the molecular weight is low, and as the melting point can be set high in view of the molecular weight, they are convenient. The preferred range of molecular weight is 300 to 1000. The starting materials may be selected from various combinations such as a di-isocyanate acid compound with a mono-alcohol, a mono-isocyanic acid with a mono-alcohol, a dialcohol with a mono-isocyanic acid, a tri-alcohol with a mono-isocyanic acid, and a tri-isocyanic acid compound with a mono-alcohol. To prevent increase of molecular weight, it is preferred to use a combination of compounds with polyfunctional groups and monofunctional groups, and it is important to use equivalent amounts of functional groups.

Among the starting materials, examples of mono-isocyanic acid compounds are dodecyl isocyanate, phenyl isocyanate and its derivatives, naphthyl isocyanate, hexyl isocyanate, benzyl isocyanate, butyl isocyanate and allyl isocyanate.

Examples of di-isocyanic acid compounds are tolylene di-isocyanate, 4,4' diphenylmethane di-isocyanate, toluene di-isocyanate, 1,3-phenylene di-isocyanate, hexamethylene

di-isocyanate, 4-methyl-m-phenylene di-isocyanate and isophorone di-isocyanate.

Examples of mono-alcohols which may be used are very ordinary alcohols such as methanol, ethanol, propanol, butanol, pentanol, hexanol and heptanol.

Among the starting materials, examples of di-alcohols are numerous glycols such as ethylene glycol, diethylene glycol, triethylene glycol, trimethylene glycol; and examples of tri-alcohols are trimethylol propane, triethylol propane and trimethanolethane, but the invention is not necessarily limited this range.

These urethane compounds may be mixed with the resin or coloring agent during kneading as in the case of an ordinary releasing agent, and used also as a kneaded, crushed toner. Further, in the case of an emulsion polymerization cohesion scorification toner, they may be dispersed in water together with an ionic surfactant, polymer acid or polymer electrolyte such as a polymer base, heated above the melting point, and converted to fine particles by applying an intense shear in a homogenizer or pressure discharge dispersion machine to manufacture a releasing agent particle dispersion of  $1\mu$  or less, which can be used together with a resin particle dispersion or coloring agent dispersion.

- Toner Other components -

The toner may also contain other components such as internal additives, charge control agents and inorganic particles. Examples of internal additives are metals such as ferrite, magnetite,

reduced iron, cobalt, nickel and manganese, alloys or magnetic bodies such as compounds containing these metals.

The various charge control agents which are generally used may also be employed here, such as quaternary ammonium salts, nigrosine compounds, dyes from complexes of aluminum, iron and chromium, or triphenylmethane pigments. Materials which are difficultly soluble in water are preferred from the viewpoint of control of ionic strength which affects cohesion and stability during melting, and of less waste water pollution.

The inorganic fine particles may be any of the external additives for toner surfaces generally used, such as silica, alumina, titania, calcium carbonate, magnesium carbonate or tricalcium phosphate, it being preferred to disperse these with an ionic surfactant, polymer acid or polymer base.

Surfactants can also be used for emulsion polymerization, seed polymerization, pigment dispersion, resin particle dispersion, releasing agent dispersion, cohesion or stabilization thereof. Examples are anionic surfactants such as sulfuric acid ester salts, sulfonic acid salts, phosphoric acid esters or soaps, and cationic surfactants such as amine salts and quaternary ammonium salts. It is also effective to use non-ionic surfactants such as polyethylene glycols, alkylphenol ethylene oxide additives or polybasic alcohols. These may generally be dispersed by a rotary shear homogenizer or a ball mill, sand mill or dyno mill containing the media.

The toner may also contain an external additive if necessary.

Examples of this additive are inorganic powders and organic particles. Examples of inorganic particles are  $\text{SiO}_2$ ,  $\text{TiO}_2$ ,  $\text{Al}_2\text{O}_3$ ,  $\text{CuO}$ ,  $\text{ZnO}$ ,  $\text{SnO}_2$ ,  $\text{Fe}_2\text{O}_3$ ,  $\text{MgO}$ ,  $\text{BaO}$ ,  $\text{CaO}$ ,  $\text{K}_2\text{O}$ ,  $\text{Na}_2\text{O}$ ,  $\text{ZrO}_2$ ,  $\text{CaO-SiO}_2$ ,  $\text{K}_2\text{O}-(\text{TiO}_2)_n$ ,  $\text{Al}_2\text{O}_3-2\text{SiO}_2$ ,  $\text{CaCO}_3$ ,  $\text{MgCO}_3$ ,  $\text{BaSO}_4$  and  $\text{MgSO}_4$ . Examples of organic particles are fatty acids and their derivatives, powdered metal salts thereof, and resin powders of fluorine resins, polyethylene resin and acrylic resins. The average particle diameter of these powders may for example be  $0.01\mu\text{m}$  to  $5\mu\text{m}$ , but is preferably  $0.1\mu\text{m}$  to  $2\mu\text{m}$ .

There is no particular limitation on the process of manufacturing the toner, but it is preferably manufactured by a process comprising the steps of (i) forming cohesive particles in a dispersion of resin particles to manufacture a cohesive particle dispersion, (ii) adding a fine particle dispersion to the aforesaid cohesive particle dispersion so that the fine particles adhere to the cohesive particles, thus forming adhesion particles, and (iii) heating the aforesaid adhesion particles which melt to form toner particles.

#### - Toner Physical properties -

It is preferred that the volume average particle diameter of the toner is from  $0.5\mu\text{m}$  to  $10\mu\text{m}$ .

If the volume average particle diameter of the toner is too small, it may have an adverse effect on handling of the toner (supplementation, cleaning properties and flow properties), and particle productivity may decline. On the other hand, if the volume average particle diameter is too large, it may have an adverse

effect on image quality and resolution due to granularity and transfer properties.

It is preferred that the toner satisfies the aforesaid toner volume average particle diameter range, and that the volume average particle distribution index (GSDv) is 1.3 or less.

It is preferred that the ratio (GSDv/GSDn) of the volume average polymer distribution index (GSDv) and number average particle distribution index (GSDn) is 0.95 or more.

It is preferred that the toner of the present invention satisfies the aforesaid volume average particle diameter range, and that the average value of the shape coefficient represented by the following equation is 1.00 to 1.50.

$$\text{Shape coefficient} = (\pi \times L^2) / (4 \times S)$$

(where, L is the maximum length of the toner particles, and S is the projection surface area of a toner particle).

If the toner satisfies the above conditions, it has a desirable effect on image quality, and in particular, granularity and resolution. Also, there is less risk of dropout and blur accompanying transfer, and less risk of adverse effect on handling properties even if the average particle diameter is small.

The storage modulus  $G'$  (measured at an angular frequency of 10 rad/sec) of the toner itself at 150°C is 10Pa to 200Pa, which is convenient for improving image quality and preventing offset in the fixing step.

<Belt fixing and smoothing apparatus>

The belt fixing and smoothing apparatus comprises a hot-pressing member, a belt member, a cooling device, and a cooling-releasing section and may further comprise other members according to necessity.

The hot-pressing member includes, but is not specifically limited to, a combination of a heating roller, a pressure roller, and an endless belt. The cooling device includes, but is not specifically limited to, cooling units that can supply cooling air and can control a cooling temperature and other conditions, and heatsinks.

The cooling-releasing section is not specifically limited, can be set according to the purpose and means a position in the vicinity of a tension roller where the electrophotographic image-receiving sheet is peeled off from the belt by action of its rigidity.

When the electrophotographic image-receiving sheet is brought into contact with the hot-pressing member of the belt fixing and smoothing apparatus, it is preferably pressurized. The sheet can be pressurized by any technique and is preferably pressurized by the application of a nip pressure. The nip pressure is preferably from 1 kgf/cm<sup>2</sup> to 100 kgf/cm<sup>2</sup> and more preferably from 5 kgf/cm<sup>2</sup> to 30 kgf/cm<sup>2</sup> for the formation of images with excellent water resistance, high surface smoothness and good gloss. The heating temperature in the hot-pressing member is equal to or higher than the softening point of the thermoplastic resin in the image-forming layer (toner-image-receiving layer), depends on the type of the thermoplastic resin but is generally preferably from 80°C to 200°C.

The cooling temperature in the cooling device is preferably 80°C or lower and more preferably from 20°C to 80°C for the sufficient solidification of the thermoplastic resin layer in the toner-image-receiving layer.

The belt member in the belt fixing and smoothing apparatus comprises a heat-resistant support film and a releasing layer arranged on the support film.

The support film is not specifically limited, as long as it has heat resistance, and is, for example, a film of a polyimide (PI), a poly(ethylene naphthalate) (PEN), a poly(ethylene terephthalate) (PET), a poly(ether ether ketone) (PEEK), a poly(ether sulfone) (PES), a poly(ether imide) (PEI), or a poly(parabanic acid) (PPA).

The releasing layer preferably comprises at least one of silicone rubbers, fluorocarbon rubbers, fluorocarbonsiloxane rubbers, silicone resins, and fluorocarbon resins. The belt member more preferably has a layer comprising a fluorocarbonsiloxane rubber on its surface, and further preferably has a layer comprising a silicone rubber on its surface, which silicone rubber layer has a layer comprising a fluorocarbonsiloxane rubber on its surface.

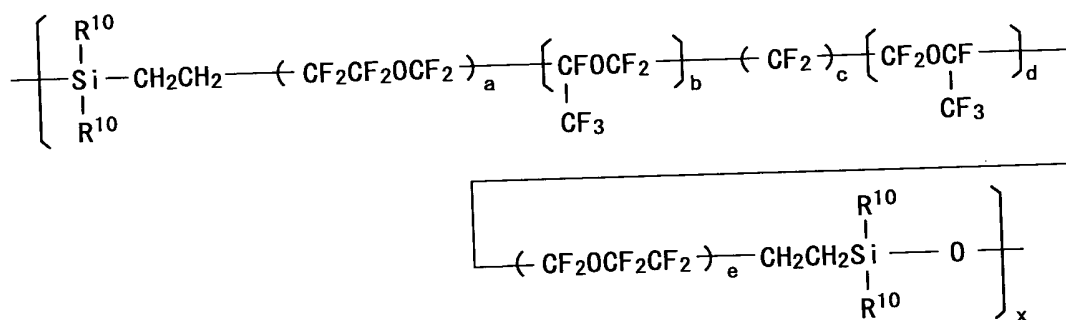
Thus, offset and belt stain in operation over the long run (about 100000 sheets output) can be prevented to thereby avoid decreased glossiness.

It is preferred that the fluorocarbon siloxane rubber has a perfluoroalkyl ether group and/or a perfluoroalkyl group in the main chain.

As the fluorocarbon siloxane rubber, a curing material comprising a fluorocarbon siloxane rubber composition containing the components (A) to (D) below are preferred.

(A) a fluorocarbon polymer having a fluorocarbon siloxane of the following general formula 1 below as its main component, and containing aliphatic unsaturated groups, (B) an organopolysiloxane and/or fluorocarbon siloxane containing two or more  $\equiv \text{SiH}$  groups in the molecule, and 1 to 4 times the molar amount of  $\equiv \text{SiH}$  groups more than the amount of aliphatic unsaturated groups in the aforesaid fluorocarbon siloxane rubber, (C) a filler, and (D) an effective amount of catalyst.

The fluorocarbon polymer of component (A) comprises a fluorocarbon siloxane containing a repeating unit represented by the following general formula 1 as its main component, and contains aliphatic unsaturated groups.



Formula 1

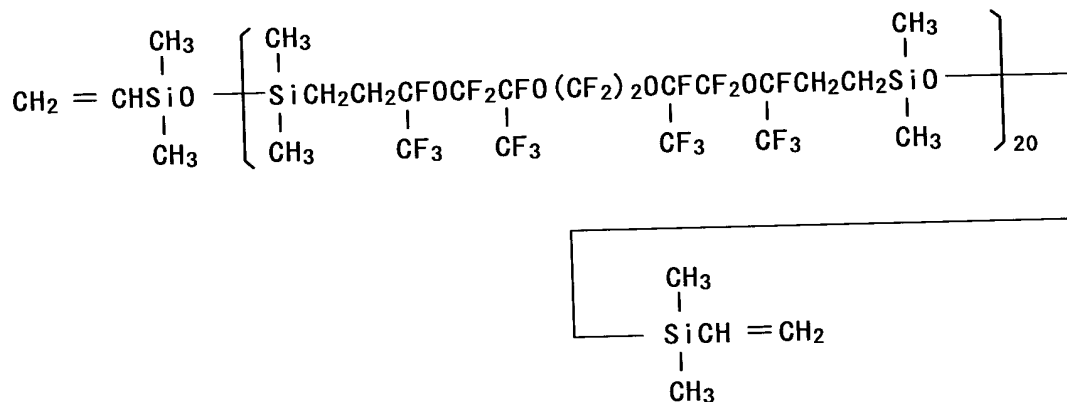
In the aforesaid formula 1,  $\text{R}^{10}$  is a non-substituted or substituted monofunctional hydrocarbon group preferably



containing 1 to 8 carbon atoms, preferably an alkyl group containing 1 to 8 carbon atoms or an alkenyl group containing 2 to 3 carbon atoms, and particularly preferably methyl.

a, e are respectively 0 or 1, b, d are respectively integers in the range 1 to 4, and c is an integer in the range 0 to 8. x is an integer equal to 1 or more, which is preferably 10 to 30.

An example of the aforesaid component (A) is the substance shown by the following formula 2:



Formula 2

In component (B), one example of the organopolysiloxane comprising  $\equiv \text{SiH}$  groups is an organohydrogenpolysiloxane having at least two hydrogen atoms bonded to silicon atoms in the molecule.

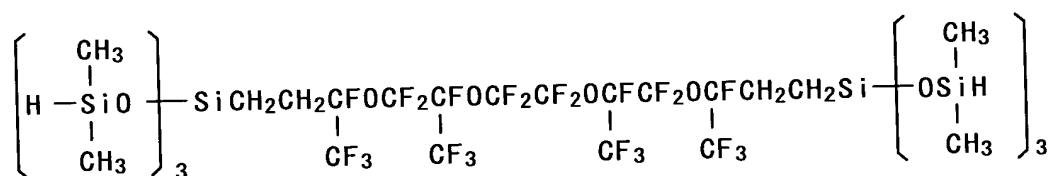
In the fluorocarbon siloxane rubber composition, when the organocarbon polymer of component (A) comprises an aliphatic unsaturated group, the aforesaid organohydrogenpolysiloxane may be used as a curing agent. Specifically, in this case, the cured product is formed by an addition reaction between aliphatic

unsaturated groups in the fluorocarbon siloxane, and hydrogen atoms bonded to silicon atoms in the organohydrogenpolysiloxane.

Examples of the organohydrogenpolysiloxanes are the various organohydrogenpolysiloxanes used in addition curing silicone rubber compositions.

It is generally preferred that the organohydrogenpolysiloxane is blended in such a proportion that the number of  $\equiv \text{SiH}$  groups therein is at least one, and particularly 1 to 5, relative to one aliphatic unsaturated hydrocarbon group in the fluorocarbon siloxane of component (A).

It is preferred that in the fluorocarbon containing  $\equiv \text{SiH}$  groups, one unit of Formula 1 or  $\text{R}^{10}$  in Formula 1 is a dialkylhydrogensiloxane, the terminal group is a  $\equiv \text{SiH}$  group such as dialkylhydrogensiloxane or silyl, and it can be represented by the following formula 3.



Formula 3

The filler which is component (C) may be various fillers used in ordinary silicone rubber compositions. Examples are reinforcing fillers such as for example mist silica, precipitated silica, carbon powder, titanium dioxide, aluminum oxide, quartz powder,

talc, sericite and bentonite, or fiber fillers such as asbestos, glass fiber and organic fibers or the like.

Examples of the catalyst which is component (D) are chloroplatinic acid which is known in the art as an addition reaction catalyst, alcohol-modified chloroplatinic acid, complexes of chloroplatinic acid and olefins, platinum black or palladium supported on a carrier such as alumina, silica or carbon, and Group VIII elements of the Periodic Table or their compounds such as complexes of rhodium and olefins, chlorotris(triphenylphosphine) rhodium (Wilkinson catalyst) and rhodium (III) acetyl acetonate, and it is preferred to dissolve these complexes in an alcohol, ether or a hydrocarbon solvent.

Various blending agents may be added to the fluorocarbon siloxane rubber composition to the extent that they do not interfere with the purpose of the invention which is to improve solvent resistance. For example, dispersing agents such as diphenylsilane diol, low polymer chain end hydroxyl group-blocked dimethylpolysiloxane and hexamethyl disilazane, heat resistance improvers such as ferrous oxide, ferric oxide, cerium oxide and octyl acid iron, and coloring agents such as pigments or the like, may be added as necessary.

The belt member can be obtained by coating the surface of the heat-resistant support film with the fluorocarbonsiloxane rubber composition and heating and curing the composition. Where necessary, the fluorocarbonsiloxane rubber composition is further

diluted with a solvent such as m-xylene hexafluoride or benzotrifluoride to yield a coating liquid, and the coating liquid is applied to the film according to a conventional coating procedure such as spray coating, dip coating or knife coating. The heating and curing temperature and time can be selected depending on, for example, the type of the support film and the production method. The coated layer is generally heated and cured at a temperature of 100°C to 500°C for 5 seconds to 5 hours.

The thickness of the releasing layer arranged on the surface of the heat-resistant support film is not specifically limited but is preferably from 1μm to 200μm, and more preferably from 5μm to 150μm for better releasing of the toner, for inhibiting offset of the toner components and for better image-fixing properties.

Examples of the belt fixing system are a method described in JP-A No. 11-352819 wherein an oilless type belt is used and a method described in JP-A No. 11-231671 and JP-A No. 05-341666 wherein the secondary image transfer and the fixing are performed at the same time. An example of electrophotographic apparatus using the fixing belt for use in the present invention is an electrophotographic apparatus having a toner-image fixing unit using a belt. The apparatus includes at least a hot-pressing member, a belt member, and a cooling unit. The hot pressing member is capable of fusing and pressurizing a toner. The belt member is capable of conveying an image-receiving sheet bearing the toner while the belt is in contact with a toner-image-receiving

layer of the sheet. The cooling unit is capable of freely cooling the heated image-receiving sheet while being attached to the fixing belt. By using the electrophotographic image-receiving sheet having the toner-image-receiving layer in the electrophotographic apparatus having the belt member, the toner attached to the toner-image-receiving layer can be fixed at a precise position without broadening in the image-receiving sheet. In addition, the fused toner is cooled and solidified while being in intimate contact with the belt member, and thus the toner-image-receiving layer receives the toner while the toner is completely embedded therein. Accordingly, the resulting toner image has no step and is glossy and smooth.

The electrophotographic image-receiving sheet for use in the present invention is suitable for an image forming process using an oilless belt, for significantly improving anti-offset properties. However, it can also be used in other image forming processes satisfactorily.

For example, by using the electrophotographic image-receiving sheet, a full color image can be satisfactorily formed while improving the image quality and avoiding cracking. The color image can be formed using an electrophotographic apparatus capable of forming full color images. A regular electrophotographic apparatus comprises a conveying section for conveying an image-receiving sheet, a latent electrostatic image forming section, a development section arranged in the vicinity of

the latent electrostatic image forming section, and an image-fixing section. Some of these apparatus further comprise an intermediate image transfer section at a center part thereof in the vicinity of the latent electrostatic image forming section and the conveying section.

For further improving the image quality, an adhesive transfer system or a heat-aided transfer system instead of, or in combination with, electrostatic transfer or bias roller transfer has been known. Specific configurations of these systems can be found in, for example, JP-A No. 63-113576 and JP-A No. 05-341666. A method using an intermediate image-transfer belt according to the heat-aided transfer system is preferred. The intermediate image-transfer belt preferably has a cooling device in a portion after image transfer procedure or in a latter half of image transfer procedure in which the toner is transferred to the electrophotographic image-receiving sheet. By action of the cooling device, the toner can be cooled to a temperature equal to or lower than the softening point or glass transition point of the binder resin used therein and can be efficiently peeled off from the intermediate image-transfer belt and transferred to the electrophotographic image-receiving sheet.

The fixing is an important step for the gloss and smoothness of the final image. For the fixing, a method wherein a hot-press roller is used and a method wherein a belt is used for image fixing are known. From the viewpoints of the image qualities such as gloss and smoothness, the belt fixing method is preferred.

Examples of the belt fixing method are a method described in JP-A No. 11-352819 wherein an oilless type belt is used and a method described in JP-A No. 11-231671 and JP-A No. 05-341666 wherein the secondary image transfer and the fixing are performed at the same time. Before hot pressing using a fixing belt and a fixing roller, primary fixing with a heat roller may be performed.

FIGs. 1 and 3 are examples of the belt fixing and smoothing apparatus. In the belt fixing and smoothing apparatus (endless press) of cooling and releasing system shown in FIG. 1, a processing section 41 includes a belt 42, a heating roller 43, a pressure roller 44, tension rollers 45, a cleaning roller 46, a cooling device 47, and conveying rollers 48.

The heating roller 43 and a pair of the tension rollers 45 are arranged inside the belt 42. The tension rollers 45 are arranged distant from the heating roller 43. The belt 42 is rotatably spanned among the heating roller 43 and the tension rollers 45. The pressure roller 44 is arranged in contact with the belt 42 and faces the heating roller 43. A portion between the pressure roller 44 and the belt 42 is pressurized by the pressure roller 44 and the heating roller 43 to thereby form a nip. The cooling device 47 is arranged inside the belt 42 between the heating roller 43 and one of the tension rollers 45. The heating roller 43 is disposed upstream in a rotating direction of the belt 42, and the one of the tension rollers 45 is disposed downstream thereof. The two conveying rollers 48 are arranged so as to face the cooling device 47 with the interposition of

the belt 42. The distance between the two conveying rollers 48 is nearly equal to the distance between the nip and one of the conveying rollers 48 and the distance between the tension roller 45 and the other conveying roller 48. The cleaning roller 46 is arranged so as to face the heating roller 43 with the interposition of the belt 42 in an opposite side to the pressure roller 44. The portion between the cleaning roller 46 and the belt 42 is pressurized by the cleaning roller 46 and the heating roller 43. The heating roller 43, the pressure roller 44, the tension rollers 45, the cleaning roller 46, and the conveying rollers 48 synchronously rotate to thereby allow the belt 42 to revolve.

The belt fixing and smoothing apparatus shown in FIG. 3 can be prepared by modifying a belt image-fixing device of an electrophotographic apparatus shown in FIG. 2 (e.g., a full color laser printer DCC-500 (trade name, available from Fuji Xerox Co., Ltd., Japan)).

The image forming apparatus 200 shown in FIG. 2 comprises a photoconductor drum 37, a development device 29, an intermediate image-transfer belt 31, a recording sheet 16, and the belt image-fixing device 25.

FIG. 3 shows the belt image-fixing device 25 arranged in the image forming apparatus 200 shown in FIG. 2.

With reference to FIG. 3, the belt image-fixing device 25 comprises a heating roller 71, a releasing roller 74, a tension roller 75, an endless belt 73, and a pressure roller 72 pressed to the heating



roller 71 with the interposition of the endless belt 73. The endless belt is rotatably supported by the heating roller 71, the releasing roller 74, and the tension roller 75.

A cooling heatsink 77 is arranged inside the endless belt 73 between the heating roller 71 and the releasing roller 74. The cooling heatsink 77 serves to forcibly cool the endless belt 73 and constitutes a cooling and sheet conveying section for cooling and conveying an electrophotographic image-receiving sheet.

In the belt image-fixing device 25 as shown in FIG. 3, an electrophotographic image-receiving sheet bearing a transferred toner image on its surface is introduced into a nip so that the toner image faces the heat roller 71. The nip is a portion at which the heating roller 71 is pressed to the pressure roller 72 with the interposition of the endless belt 73. When the electrophotographic image-receiving sheet passes through the nip between the heating roller 71 and the pressure roller 72, the toner image is heated, fused and thereby fixed on the electrophotographic image-receiving sheet.

Specifically, the toner is substantially heated to a temperature of about 120°C to about 130°C in the nip between the heating roller 71 and the pressure roller 72 and is thereby fused, and thus the toner image is fixed onto the image-receiving layer of the electrophotographic image-receiving sheet. The electrophotographic image-receiving sheet bearing the toner image on the image-receiving layer is then conveyed with the endless belt 73 while its surface image-receiving layer is in intimate contact with

the surface of the endless belt 73. During conveying, the endless belt 73 is forcedly cooled by the cooling heatsink 77 to thereby cool and solidify the toner image and the image-receiving layer, and the electrophotographic image-receiving sheet is then peeled off from the endless belt 73 due to its own rigidity by action of the releasing roller 74.

A remained toner and other unnecessary substances on the surface of the endless belt 73 after the completion of the releasing process are removed by a cleaner (not shown) for another image-fixing process.

The image forming process of the present invention can cool the components in a shorter distance and thereby reduce the size of the apparatus. In addition, the method reduces energy consumption of a cooling fan and thereby can conserve energy.

(Image Forming Apparatus)

FIG. 4 is a schematic diagram of a color copying machine (image forming apparatus) constituting the electrophotographic printing system of the present embodiment. The copying machine 100 comprises a main body 103 and an image reader (document read means) 102. The main body 103 houses an image output section (image-forming section) and a image-fixing device 101.

The image forming section comprises an endless intermediate image transfer belt 9 which is spanned over plural tension rollers and is rotated, electrophotographic image forming units 1Y, 1M, 1C, and 1K, a belt cleaner 14 facing the intermediate image transfer belt

9, a secondary image transfer roller 12 facing the intermediate image transfer belt 9, sheet tray 17 for housing sheets of plain paper (image-receiving sheet) 18(S) and sheets of dedicated glossy paper (image-receiving sheet) 18(P), respectively, a pickup roller 17a, a pair of conveyer rollers 19 and 24, a pair of resist rollers 20, and a second paper output tray 26. The electrophotographic image forming units 1Y, 1M, 1C, and 1K are arranged from upstream to downstream of a rotation direction of the intermediate image transfer belt 9 and serve to form yellow, magenta, cyan, and black color toner images, respectively.

Each of the electrophotographic image forming units 1Y, 1M, 1C, and 1K comprises, for example, a photoconductive drum 2, an electrostatic charger roller 3, a development device 5, a primary image transfer roller 6, a drum cleaner 7, and a charge eliminating roller 8.

The belt image-fixing device 101 is arranged below the image reader 102 and above the image forming section (e.g., at image transfer position). The image-fixing device 101 is positioned directly above the image forming section (e.g., the intermediate image transfer belt 9) and directly under the image reader 102. The entire conveying path for the image-receiving sheet 18 extending from the second image transfer position to the image-fixing device 101 is positioned directly above the image forming section (e.g., the intermediate image transfer belt 9). A primary image-fixing line connecting between the secondary image transfer position and the

primary image transfer position has a substantially normal vertical component. An image-fixing line connecting between the secondary image transfer position and the image-fixing position has a vertical component less than a horizontal component thereof. The image-receiving sheet 18 is ejected from the image-fixing device 101 to an area directly above the image forming section (e.g., the intermediate image transfer belt 9).

The configuration as above can yield the following advantages. Firstly, the entire apparatus 100 occupies as little space (in particular, as little footprint) as possible even though it comprises the image-fixing device 101. Secondly, the electrophotographic image-receiving sheet 18 is ejected at a relatively high position, and the apparatus can be operated easily.

The present invention will be illustrated in further detail with reference to several examples and comparative examples below, which are not intended to limit the scope of the present invention.

#### EXAMPLES 1 TO 3, COMPARATIVE EXAMPLES 1 AND 2

A series of electrophotographic image-receiving sheets having a width of 42 cm and different raw paper thickness and thereby different heat capacities as shown in Table 1 were prepared according to Examples 1 to 3, and Comparative Examples 1 and 2 in the following manner.

##### - Preparation of support -

A woodfree paper having a basis weight of 160 g/m<sup>2</sup> and a

thickness shown in Table 1 was used as the raw paper. A 7:3 by mass blend of a high-density polyethylene (HDPE) and a low-density polyethylene (LDPE) was applied to a thickness of 15  $\mu\text{m}$  to the back side of the raw paper by extrusion coating at 310°C and thereby yielded a backside polyethylene layer thereon.

A low-density polyethylene (LDPE) was then applied to a thickness of 13  $\mu\text{m}$  to the front side of the raw paper in the same manner as above and thereby yielded a front side polyethylene layer thereon. Thus, a double-sided polyethylene-laminated paper was prepared as a support.

- Formation of front-side undercoat layer -

A composition for a front-side undercoat layer was prepared by mixing 5 parts by mass of gelatin and 95 parts by mass of water. The composition was applied to the front side of the support using a wire coater, was dried and thereby yielded a front-side undercoat layer having a thickness after drying of 5  $\mu\text{m}$ .

- Formation of backside layer -

A composition for a backside layer was prepared by mixing 100 parts by mass of an aqueous acrylic resin Hiros XBH-997L (trade name, available from Seiko Chemical Industries Co., Ltd., Japan) having a solid content of 28.3% by mass, 4.5 parts by mass of a paraffin wax Hydrin D-337 (trade name, available from Chukyo Yushi Co., Ltd., Japan) having a solid content of 30% by mass, and 33 parts by mass of ion-exchanged water. This composition was applied to the backside of the support using a wire coater, was dried

and thereby yielded a backside layer having a coated amount of 8.2 g/m<sup>2</sup> after drying.

- Formation of interlayer -

A composition for an interlayer was prepared by mixing 100 parts by mass of a water-dispersed acrylic resin Hiros HE-1335 (trade name, available from available from Seiko Chemical Industries Co., Ltd., Japan) having a solid content of 45% by mass, 2 parts by mass of a surfactant Nissan Rapisol B-90 (trade name, available from NOF Corporation, Japan) having a solid content of 10% by mass, and 30 parts by mass of ion-exchanged water. The composition was applied to the surface of the front-side undercoat layer using a wire coater, was dried and thereby yielded an interlayer having a thickness after drying of 5  $\mu$ m.

- Formation of toner-image-receiving layer -

A composition for a toner-image-receiving layer was prepared by mixing 100 parts by mass of a water-dispersed polyester resin, 5 parts by mass of a releasing agent, 7.5 parts by mass of an aqueous dispersion of a white pigment, and 8 parts by mass of a surfactant. The water-dispersed polyester resin was Elitel KZA sample (trade name, available from Unitika Ltd., Japan) having a solid content of 30% by mass and a glass transition point Tg of 59°C. The releasing agent was carnauba wax Cellosol 524 (trade name, available from Chukyo Yushi Co., Ltd., Japan). The water dispersion of a white pigment was a water dispersion comprising TiO<sub>2</sub> TAIPAQUE R780-2 (trade name, available from

Ishihara Sangyo Kaisha, Ltd., Japan) as the white pigment and a polymer dispersing agent. The surfactant was Nissan Rapisol D-337 (trade name, available from NOF Corporation, Japan) having a solid content of 10% by mass. The above-prepared composition was applied to a thickness after drying of 7  $\mu\text{m}$  onto the interlayer using a wire coater, was dried and thereby yielded a series of electrophotographic image-receiving sheets according to Examples 1 to 3 and Comparative Examples 1 and 2.

A series of belt members having different heat capacities were prepared by changing the thickness of the support and the material for the releasing layer as shown in Table 1.

Each of the above-prepared electrophotographic image-receiving sheets was subjected to an image fixing process under the following image fixing conditions using the belt image-fixing apparatus shown in FIG. 3 obtained by modifying the image-fixing unit of the full color laser printer DCC-500 (trade name, available from Fuji Xerox Co., Ltd., Japan) shown in FIG. 2.

<Belt member>

Support of belt: a polyimide (PI) film having a width of 50 cm and a thickness of 80  $\mu\text{m}$ , 100  $\mu\text{m}$ , 150  $\mu\text{m}$ , or 250  $\mu\text{m}$

Releasing layer of belt:

(1) SIFEL

A fluorocarbonsiloxane rubber precursor SIFEL 610 (trade name, available from Shin-Etsu Chemical Co., Ltd., Japan) was vulcanized and cured and thereby yielded a fluorocarbonsiloxane

rubber film 50  $\mu\text{m}$  thick.

## (2) Silicone rubber

A silicone rubber DY35-796AB (trade name, Dow Corning Toray Silicone Co., Ltd., Japan) was molded into a silicone rubber film 50  $\mu\text{m}$  thick.

### <Heating condition>

Temperature: 140°C

### <Cooling process>

Cooling device: a heatsink 80 mm long

Speed: 32 mm/sec or 53 mm/sec

Transit time: 1.5 sec or 2.5 sec

TABLE 1

Component		Ex. 1	Ex. 2	Ex. 3	Com. Ex. 1	Com. Ex. 2
Belt	Support (PI) thickness ( $\mu\text{m}$ )	80	100	80	150	250
	Releasing layer material	SIFEL	SIFEL	silicone rubber	SIFEL	SIFEL
	Releasing layer thickness ( $\mu\text{m}$ )	50	50	50	50	50
	Heat capacity per unit area (J/K/m <sup>2</sup> )	218.4	251.8	218.4	335.5	502.7
Toner	Heat capacity per unit area (J/K/m <sup>2</sup> )	16.9	16.9	16.9	20	20
Image-receiving sheet	Raw paper thickness ( $\mu\text{m}$ )	155	200	155	330	330
	Heat capacity per unit area (J/K/m <sup>2</sup> )	280.8	335	280.8	491.7	491.7
Total heat capacity per unit area (J/K/m <sup>2</sup> )		516.1	603.7	516.1	847.2	1014.4



TABLE 2

Speed	Component	Heat capacity per unit time (J/K/sec)				
		Ex. 1	Ex. 2	Ex. 3	Com. Ex. 1	Com. Ex. 2
32 mm/sec	Belt	3.49	4.03	3.49	5.37	8.04
	Toner	0.23	0.23	0.23	0.27	0.27
	Sheet	3.77	4.50	3.77	6.61	6.61
	Total	7.50	8.76	7.50	12.25	14.92
53 mm/sec	Belt	5.79	6.67	5.79	8.89	13.32
	Toner	0.38	0.38	0.38	0.45	0.45
	Sheet	6.25	7.46	6.25	10.95	10.95
	Total	12.41	14.51	12.41	20.28	24.71

The heat capacities can be determined according to a conventional procedure. Namely the heat capacities can be determined by calculation from the measured density, thickness, and specific heat of each layer of the belt member, each layer of the electrophotographic image-receiving sheet, and the toner. For example, the heat capacities determined by calculation on Example 1 are shown in Table 3.

TABLE 3

		Density (g/cm <sup>3</sup> )	Thickness (μm)	Weight (g/m <sup>2</sup> )	Specific heat (kJ/kg/K)	Heat capacity (J/K/m <sup>2</sup> )	
		A	B	A×B	C	A×B×C	Total
Belt	Releasing layer (SIFEL)	1.80	50	90	0.94	84.6	218.4
	Support (PI)	1.48	80	118.4	1.13	133.8	
Toner		1.35	10	13.5	1.25	16.9	16.9
Sheet	Image-receiving layer	1.35	7	9.5	1.25	11.8	280.8
	Interlayer	1.35	5	6.8	1.42	9.6	
	PE layer	1.05	13	13.7	2.3	31.4	
	Raw paper	1.03	155	159.7	1.17	186.8	
	PE layer	0.95	15	14.3	2.3	32.8	
	Backside layer	1.35	5	6.8	1.25	8.4	
						Total	516.1

Each of the electrophotographic image-receiving sheets according to Examples 1 to 3 and Comparative Examples 1 and 2 was subjected to an image-fixing process using the belt image-fixing apparatus shown in FIG. 3 obtained by modifying the image-fixing unit of the full color laser printer DCC-500 (trade name, available from Fuji Xerox Co., Ltd., Japan) shown in FIG. 2. In this procedure, the surface temperatures of the releasing section and the image-receiving layer and deterioration in image quality were determined by the following methods. The results are shown in Table 4.

<Surface temperatures of releasing section and image-receiving layer>

The surface temperatures of the releasing section and the image-receiving layer were determined with an infrared thermometer IT-550F (trade name, available from Horiba, Ltd., Japan).

<Deterioration in image quality>

After allowing 100000 plies of the electrophotographic image-receiving sheet to pass through the apparatus continuously, the image on the surface of the sheet was visually observed. The degree of deterioration in image quality was determined according to the following criteria.

[Criteria]

AA: No change is observed.

A: Little minute defect is observed but trivial in practical use.  
 B: Defects are observed although the image has slight gloss.  
 C: Defects are observed and the image has decreased gloss.  
 CC: Increased defects are observed and the image has significantly decreased gloss.

TABLE 4

Speed		Ex. 1	Ex. 2	Ex. 3	Com. Ex. 1	Com. Ex. 2
32 mm/sec	Surface temperature (°C)	64	68	64	76	79
	Deterioration in image quality	AA	AA	A	A	B
53 mm/sec	Surface temperature (°C)	73	77	73	83	87
	Deterioration in image quality	AA	B	B	C	CC

Tables 1 to 4 show that electrophotographic image-receiving sheets having a heat capacity per unit area of 500 J/K/m<sup>2</sup> or less can be used when belt members having a heat capacity per unit area of 300 J/K/m<sup>2</sup> or less are used. These tables also show that by using a highly releasing material in the belt member, the method has high suitability in operation over the long run.

According to the present invention, images can be produced at high speed and energy can be conserved, and offset and stain of a belt in operation over the long run can be prevented, by specifying the heat capacity of the belt member and the total heat capacity of the belt member, the electrophotographic image-receiving sheet, and the toner to be cooled.